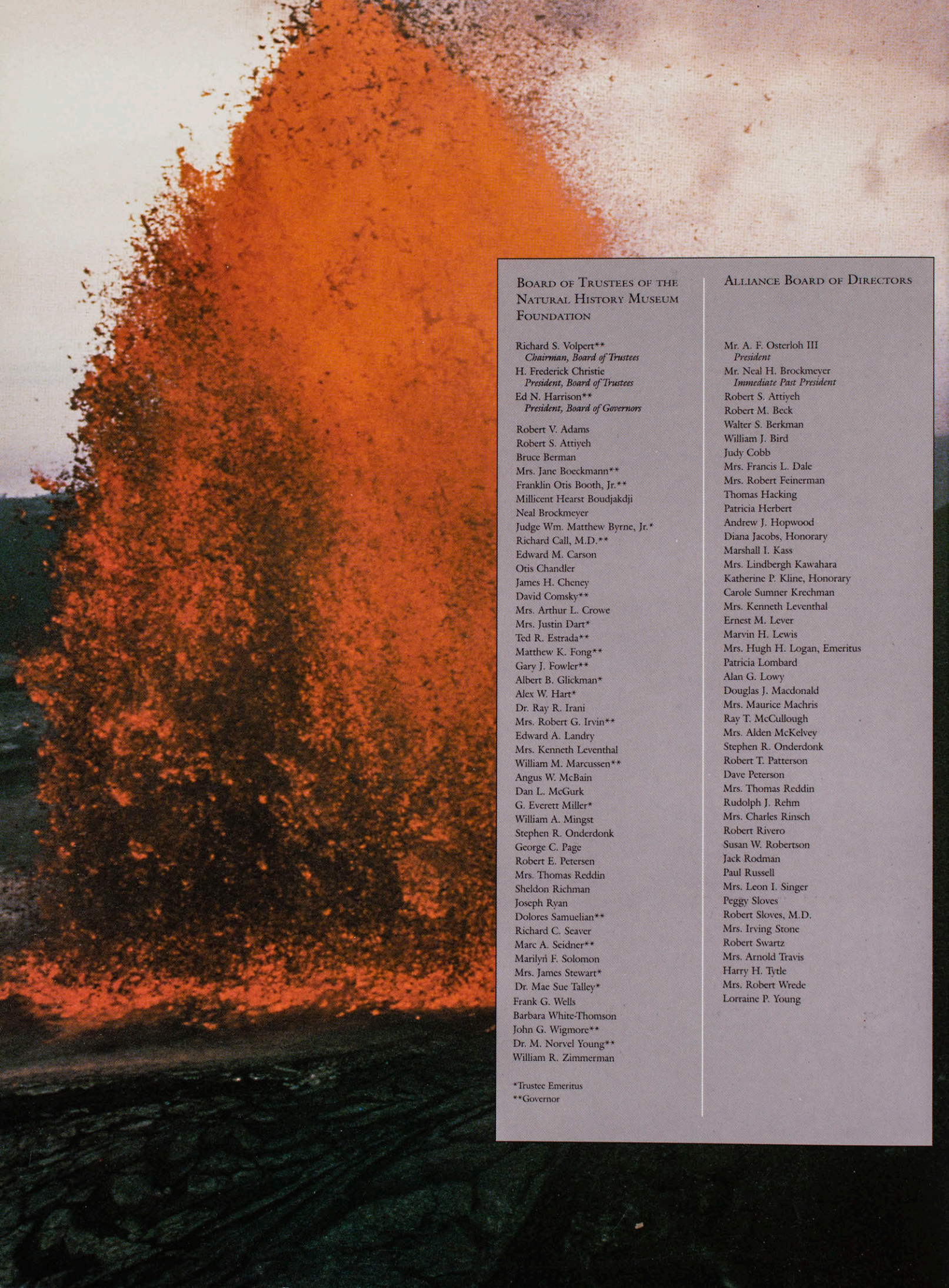
# TERRA

MAGAZINE OF THE
NATURAL HISTORY MUSEUM
OF LOS ANGELES COUNTY

VOLUME 31, NUMBER 2
WINTER 1992

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During the 1984 eruption of Mauna Loa, the only active volcano on Hawaii other than Kilauea, Dr. Art Montana uses a thermocouple to measure the temperature of the lava. Photo by Professor Joe Halbig, University of Hawaii, Hilo. See story, page 6.

# TERRA

THE NATURAL HISTORY MUSEUM OF LOS ANGELES COUNTY
VOLUME 31 NUMBER 2
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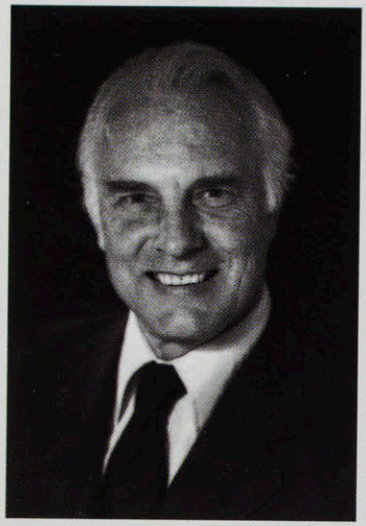
< Waning eruption at Pu'u O'o, a cinder cone on the flank of Kilauea volcano. Photo by C.C. Heliker, U.S. Geological Survey.

# Museum on the Move



Charles Hogue

## ACKNOWLEDGEMENTS

■ **THANKS** The photograph on the cover of the Fall 1992 issue of TERRA, of Masami Teraoka's painting, *New Views of Mt. Fuji/La Brea Tar Pits and Pleasure Boats* was taken by Ken Cohen, New York.

The editors thank Tari Mattox and Jane Takahashi of the U.S. Geological Survey for their assistance with the article "Inside Active Volcanoes" in this issue.

## STAFF

■ **DR. CHARLES LEONARD HOGUE, CURATOR OF ENTOMOLOGY, 1935-1992** The world entomological community and the Natural History Museum have been numbed by the loss of a prominent and talented figure, Dr. Charles L. Hogue, who died July 20.

Hogue began his lifelong association with the museum in his high school years in the Natural History Workshop for gifted students, taught by science specialist Gretchen Sibley, who originated the workshop. In 1962, four months after receiving his doctorate from U.C.L.A., he was hired as the museum's Curator of Entomology, the position he held until his death.

During his tenure at the museum, Hogue produced four books and more than 100 important scientific and popular articles. He took great satisfaction in sharing his knowledge about the fascinating ways of insects and was a steady source of information, specimens, photographs, and advice to the news and entertainment media, consulting on projects from Hollywood film dramas to National Geographic specials. His work demonstrates his superb gifts both as a scientific illustrator and a natural history photographer; his images have appeared in many articles and books besides his own.

Hogue was a world authority on the fly family Blephariceridae and related groups that inhabit waterfalls in mountainous regions, and he described several new genera and species. On Cocos Island in Costa Rica, he discovered most of the 14 species of arthropods that have been named in his honor (e.g., the moth *Oxydia hoguei*).

As a curator, Hogue oversaw the growth of the museum's insect collection into a major assemblage, from half a million to the nearly six million specimens the museum owns today. He was an Adjunct Professor at the University of Southern California, taught the museum's Natural History Workshops for nearly a decade, and was a co-leader of eleven U.C.L.A. field ecology courses to the Amazon and Napo Rivers in Peru and Colombia. His knowledge and love of the natural history and cultures of tropical America made a deep and lasting impression on the lives of his students. His memory will be harbored in the Hogue Memorial Fund for the protection and management of the natural resources of the Pacaya-Samiria National Reserve in the Peruvian rain forest. Contributions may be sent to The Nature Conservancy, 1815 N. Lynn Street, Rosslyn, VA 22209, attention Dan Quinn.

■ **MUSEUM NAMES DEPUTY DIRECTOR** Catherine Ingram Krell has been named Deputy Director of Marketing and Public Affairs for the museum.

In this newly created position, Krell is responsible for directing all aspects of the marketing of educational and public programs, exhibits, retail operations, and image at the Natural History Museum and its affiliate operations, the George C. Page and William S. Hart museums, the Petersen Automotive Museum, and the Burbank Museum. The Burbank and Petersen facilities are scheduled to open in early 1993 and early 1994, respectively.

John DeLeon

Catherine Krell

Krell has an extensive management background in marketing. Prior to joining the museum, she headed her own firm, Marketing Directions. Before that, she held a senior management position with McCann Erickson, Inc. in Los Angeles and was a senior account executive with J. Walter Thompson, Inc. Her 19 years in the advertising field include directing such major accounts as Scott Paper Products, Warner Lambert, Hills Brothers Coffee, and Hilton Hotels Worldwide.

Krell received her Master's degrée from the American Graduate School of International Management in Glendale, Arizona, and her Bachelor's degree from Willamette University in Salem, Oregon. She resides with her husband and two children in Pasadena, where she has served on community boards such as the Junior League, the Pasadena Historical Society, and the La Canada/Crescenta YMCA.

■ **DIRECTOR OF PLANNED GIVING NAMED** Charles E. Hovorka has been named Director of Planned Giving, with responsibility for major gifts and deferred giving at the Natural History Museum. His extensive experience in the nonprofit field includes 31 years with the southern California chapter of the Arthritis Foundation, of which he served as president from 1975 to 1991. In 1991 he became president emeritus and began private consulting for non-profit organizations.

■ **MUSEUM NAMES DIRECTOR OF DEVELOPMENT** The Natural History Museum recently named Susan Crow the new Director of Development for the museum. Crow brings with her extensive experience in non-profit organizations in the areas of development and grants.

Most recently, Crow was director of development at the Otis/Parsons School of Art and Design. Her new position is her second at the museum; she previously served as director of special projects

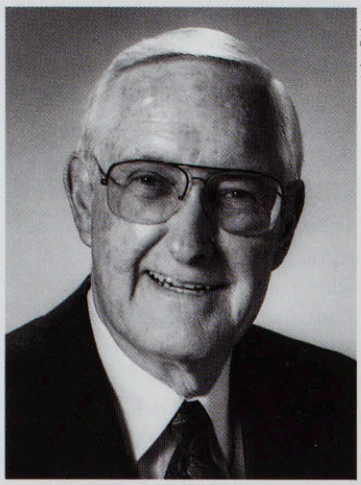
in the Office of Development. Crow has also worked as Program Officer for the California Council for the Humanities, Assistant Director of the U.S.C. Center for the Humanities, and Contract and Grants Administrator for U.C.L.A. She has edited numerous manuscripts for scholarly publications, researched and written proposals for universities and non-profit organizations, and developed presentations for such organizations as U.C.L.A., U.S.C., the National Endowment for the Humanities, and the American Library Association.

Crow assumes responsibilities formerly held by Susan E. McCarthy, who was Director of Development until mid-1992, when she was appointed Director of Cultural and Recreational Services for the City of Santa Monica.

Outside of work, Crow participates in community service projects at the Marlborough School and the Center for Early Education.

■ **DEVELOPMENT STAFF REORGANIZED** With the appointments of new marketing, development, and grant directors, the Natural History Museum has reorganized its development staff. John Charnay, formerly Marketing Director, will now oversee the museum's Capital Campaign, with specific responsibility for the Petersen Automotive Museum and the Journey Through Time permanent exhibit hall. Agnes Hess now has responsibility for the administration and coordination of the Development Office, and Marijo Racciatti, who was Director of Membership, has joined the development team as Assistant Director, Major Gifts. Sue Gloede is now Director of Membership and continues to oversee Special Events and Alliance Affairs.

■ **ANTHROPOLOGIST PROMOTED** The Natural History Museum is pleased to announce the promotion of Margaret Ann Hardin from Associate Curator to full Curator of Anthropology. Dr. Hardin,


John DeLeon

Charles Hovorka

John DeLeon

Susan Crow

John DeLeon

Matt Roth

who is Section Head of Anthropology, is a specialist in the history of museum collections, the ethnography of pottery making, and the iconography of ceramic design. She has overseen the conception, design, and installation of the museum's new Times Mirror Hall of Native American Cultures.

Dr. Hardin is a graduate of the University of Michigan and holds a Ph.D. in Anthropology from the University of Chicago. She has conducted extensive field work on variability in ceramic design, working with contemporary potters in Mexico — in a Tarascan village in Michoacán, and in the United States — at Zuni Pueblo. Dr. Hardin has written a number of articles and book chapters, many on pottery construction and painting styles. With the Native American Hall opening, she will resume her research on the history of Zuni ceramics and the current revival of pottery making at Zuni Pueblo.

■ **STUDENTS CITED FOR DISTINCTION** Lynn Tran and Lulu Wang, Alhambra High School student scientists at the museum, have received numerous awards from their school and from the Los Angeles County Science Fair for the excellence of their research in the museum's Invertebrate Zoology Section under the guidance of Dr. Gordon Hendler. Both students are recent graduates of the museum's Research Apprentice Program. Tran's study deals with the reproduction of *Amphiura carchara*, an unusual deepsea brittlestar that incubates embryos and bears live young. Wang is investigating the taxonomy of an ecological indicator species, *Amphiodia urtica*, and several closely related brittlestars.

In recognition of their accomplishments, the two students also received other awards, Tran a scholarship from Earthwatch and Wang research support from the Southern California Coastal Water Research Project. Wang was one of a small number of students invited to give presentations at the American Association for the Advancement of Science in Boston in December 1992. Her brittlestar research is of considerable importance for agencies monitoring marine ecological conditions.

■ **HISTORY DIVISION HIRES NEW CURATOR** In June the History Division welcomed Matthew Roth, the new Curator and Section Head for Transportation and Communication. His primary initial responsibility will be the planning and preparation of exhibits at the Petersen Automotive Museum.

For 12 years Roth managed HRC, Inc., a consulting firm in Hartford, Connecticut, that organized exhibits and created programming for museums and other agencies that interpret history to the public. He served as project director for numerous exhibits and also has designed and operated various kinds of tours of cultural landscapes — by foot, bus, and canoe — in locations as diverse as the Mississippi River in Minneapolis, the Florida Everglades, and the Naugatuck River in western Connecticut.

Roth's scholarly interests include the history of American metalworking technology and the history of business, from which his interest in the automotive field arose. Another of Roth's scholarly pursuits is the history of the cultural landscape, which includes urban ecology and the built environment. His publications include books on bridges and transportation systems, a book on the history of an industrial city, and a forthcoming work on the role of small business in the origin and development of the American metalworking industry. Roth holds an M.A. from the University of Delaware in the history of technology and museum studies.

## GRANTS

■ **HISTORY DIVISION AWARDED MAJOR GRANT** The National Endowment for the Humanities (N.E.H.) has awarded

Christopher Barr Photography

Habitats Lab

On the evening of February 21st, museum members explored all five floors of the Natural History Museum at the 1992 Open House. Members previewed the Times Mirror Hall of Native American Cultures, set to open in early 1993, saw presentations set up in various locations by the History Division, and took part in activities arranged by Education Division staff in the Discovery Center. Exotic specimens attracted members to all the Life Sciences departments, while mold-making in the Paleontology Section and demonstrations in Exhibits drew crowds to the upper floors. Members purchased unique items at a special sale organized by museum stores. Refreshments were provided by Ben & Jerry's Ice Cream, FIBAR, Garden of Eatin', Hansen Beverage Company, Lawry's Foods, Mother's Cake and Cookie Company, Sparkletts, and Trader Joe's.

Christopher Barr Photography

Insect Zoo

Christopher Barr Photography

Herpetology

the History Division $1,000,000 for the preservation of its material culture collections. These collections will be housed at the History Collections Center, now under construction at the Petersen Museum. Due to the size and diversity of the collections, the History Collections Center will have the largest and most complex storage system in any American museum, featuring a tightly controlled environment and complete computerized records of the collection. The million dollar matching grant is the largest federal award ever received by the museum and is the maximum allowance available from N.E.H.'s National Heritage Preservation Program, which awarded the grant. The History Collections Center will be completed in five years at a total cost of nearly $5 million.

■ **EARTHMOBILE ROLLING ALONG** In May the Gluck Foundation awarded an additional $52,000 for expansion of the Education Division's Earthmobile project. The grant, based on needs that became evident in the first year of operations, will run for the remaining 2½ years of the project. The grant supports two additional staff people to work in the classroom and on the truck, a mobile museum that brings science and ecology to elementary school children of the Los Angeles Unified School District.

■ **ELISE G. AND GILES W. MEAD FOUNDATION GRANT TO EQUIP MOLECULAR SYSTEMATICS LABORATORY** The Life Sciences Division has received a $26,000 grant from the Mead Foundation to match a 1991 equipment grant by the National Science Foundation. The funds will be used to purchase specialized equipment needed to study DNA from specimens in the museum's collections. The information gained will be used in reconstructing evolutionary histories of many kinds of plants and animals and in understanding the conservation genetics of endangered species. Curators in the Life Sciences Division continue to work with the Development Office to secure funding for the construction, operation, and endowment of the new biochemical and molecular systematics laboratory in which the DNA research will be conducted.

■ **ROBINSON'S SUPPORTS MUSEUM CALENDAR** Robinson's has donated $10,000 for educational programming to the Natural History Museum. The gift will support publication of the museum's bimonthly calendar, which carries announcements of exhibitions, classes, field trips, lectures, and special events for museum members and the general public. Robinson's has been named the official sponsor of CALENDAR, which displays a notice crediting the department store group for its contribution.

## NEWS

■ **THE GEORGE C. PAGE MUSEUM MISSION PROGRAM** The Education Division of the George C.Page Museum finished its second year of special summer activities for youth aged 5 to 16 who are served by the downtown Fred Jordan and Union Rescue Missions and by the Pico Gardens Housing and Para Los Ninos programs. The program provides these children an opportunity to learn more about the Rancho La Brea Tar Pits and the Page Museum while spending a day in a comfortable environment.

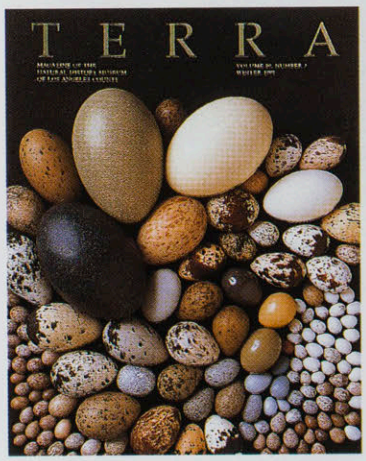
Mission vans bring the children to the museum for a day filled with tours, craft activities, and lunches provided by local restaurants Marie Callendar's, Out to Lunch, the Soup Exchange, and the Sizzler. Activities include word games, making a book or board game based on the trip to the Tar Pits, coloring, sketching, origami, and leaf-rubbing. Older children receive behind-the-scenes tours of the laboratory and Pit 91. The Page Mission Pro-

gram is seeking funding for next summer, to again provide children with an opportunity to leave their stressful environment for a day and discover a broader world.

## AWARDS

**THE EARTHMOBILE ON THE STREETS OF LOS ANGELES** The past year has been one of excitement, recognition, and expansion for the Earthmobile project. At its annual meeting in Baltimore, the American Association of Museums gave the 18-wheeled exhibition its Curators' Committee's highest exhibit honors. It was named one of four winning exhibits developed in the United States and Canada for 1992. The award was presented to Education Division staff, who were accompanied by a representative from the New York-based Maxwell H. Gluck Foundation, which funded the Earthmobile project.

**TERRA WINS DESIGN AWARD** The Winter 1991 issue of TERRA won a 1992 Award of Merit from the American Association of Museums for excellence in design.




The competition, which considered 1,639 entries in book, calendar, journal, newsletter, magazine, and other categories, honored six magazines. The winning TERRA issue featured a stunning cover photograph of avian eggs, shot by Clark Sumida of the Western Foundation of Vertebrate Zoology. TERRA is designed by Dana Levy of Perpetua Press.

**MUSEUM'S TV SPOT WINS TOP NATIONAL AWARD** "Awesome," the Natural History Museum's television public service announcement (PSA) produced by the public relations department, won two top awards at the American Association of Museums' 1992 competition. The PSA won first place in the television public service category, and it won the Silver Muse award in the AAM's Media and Technology competition, which pitted first place winners in eight categories against each other for gold, silver, and bronze trophies. The announcement may be seen on all six local television stations.

## DEVELOPMENT

**FELLOWS** Spring 1992 was busy for the Fellows, beginning with an opportunity to watch the gray whale migration off southern California. Mammalogist John Heyning led a chartered journey from San Pedro and guided the day to a conclusion with a behind-the-scenes tour of the Cabrillo Marine Museum. In April, Joan Wrede greeted Fellows for an informal living room discussion on Sherpa culture. Guest speaker Cindy Tolle shared an array of fascinating slides and climbing stories. The month of April also brought the Fellows to the museum for the tenth-anniversary Dinosaur Ball, which gave lords and ladies an opportunity to support museum educational programs while returning to the Age of Chivalry for an evening of fine dining and dancing. Ball Chair Maryann Rinsch arranged to have medieval knights and knaves greet guests, and Alliance Board members were attired in costumes generously provided by the Walt Disney Corporation. At the end of April, Fellows' children celebrated the opening of the Insect Zoo with its director, Dr. Art Evans.

In May the Fellows joined the Shona Sculpture Committee, chaired by A. F. Osterloh III, in welcoming the Ambassador of Zimbabwe to the opening night of the very successful sculpture sale. Also that month, Claire Bogaard, founder of Pasadena Heritage, led the Fellows through the streets of Pasadena on a wonderful tour of architectural treasures — a fine afternoon that ended with wine and cheese on the terrace of the elegant Gamble House. History Division Chief Janet Fireman prepared the way with a pre-tour talk at the museum.

In July, the Fellows sought the El Segundo Blue Butterfly, and found it — in its habitat on the sand dunes just west of LAX; the airport's runways actually cross the butterfly's habitat. Fellows enjoyed hearing about the wide variety of plans for fortifying the animal's reserve, and for restoring this unique habitat to its natural state, from biologist Rudy Mattoni, who is directing the restoration efforts.

In September, the John Carter Brown Library Board joined the Fellows for a tour of the magnificent exhibit Encountering the New World, 1493-1800.

Ray McCullough will chair the Fellows for the 1992-1993 fiscal year. He and his wife Nancy add a special spark to the Fellows experience. The following individuals are warmly welcomed to the Fellows Family: Mr. and Mrs. Bruce Berman, J. Lynn Dunkley, Mr. and Mrs. Lawrence Field, Mr. and Mrs. Stuart Kaplan, Dr. and Mrs. Elliot Ponchick, Mr. and Mrs. John Edd Stepp, Jr., Robert Swartz and Grace Labatt.

**BUSINESS ASSOCIATES** The final meeting of the 1991-1992 Business Associates luncheon series was held at the George C. Page Museum. Dale Laurance, Executive Vice President and Senior Operating Officer of Occidental Petroleum Corporation, spoke to over 70 Business Associates and guests about corporate restructuring and the global economy of the 1990s. The museum is pleased to welcome new Business Associates CYRO Industries, Capital Bank, Countrywide Funding Corporation, and Baker and Hostetler, McCutchen Black.

Grants from the BankAmerica Foundation and the Ledler Foundation led the museum's environment initiatives, providing educational programs, tours, and workshops that promote environmental awareness. The museum recognized the Wells Family Charitable Foundation, the Pardee Foundation, and Allied-Signal Inc., for their contributing support of these vital projects.

The Jacobs Family Foundation, the Weiler Foundation, Occidental Petroleum Corporation, and TRW provided generous support for the Museum Research Apprentice Program. This education project invites talented Los Angeles high school students to conduct advanced scientific study under the supervision of museum curators. Participants graduate from the program with an enhanced awareness of career opportunities in science and valuable skills to further their development. Sony Pictures Entertainment, Countrywide Funding Corporation, the Stein Foundation, and Southern California Edison are also recognized for contributions to this important outreach effort.

A generous gift from the ARCO Foundation in support of Free Day provides free admission to the public one day every month. The Leavey Foundation provided important support for school tours. American Express is recognized for its commitment to museum education programs. MCI Telecommunications, Marc Seidner, and Ben and Jerry's Ice Cream have contributed greatly to the success of the American Indian Festival.

# Inside Active Volcanoes

## A Comparison of Kilauea and Mt. St. Helens

*by Art Montana*

Opposite
Topography of part of the solid surface of the Pacific basin and North American continent. Note the chain of islands and seamounts that extends from Hawaii to the Aleutian Islands, with a bend north of Midway. Note also the mid-ocean ridge called the East Pacific Rise, which trends north off the coast of South America, entering land near the Salton Sea in southern California and becoming the San Andreas Fault. It reenters the Pacific Ocean just north of San Francisco at Pt. Reyes. See detail, page 10. From *World Ocean Floor,* by Bruce C. Heezen and Marie Tharp, 1977.

Close-up of lava fountain at Pu'u O'o. Rapid flow is typical of the very fluid Hawaiian lavas. The larger flows from the 1984 eruption of Mauna Loa posed a serious threat to Hilo. In 1923, the 23rd Bomb Squadron of the U.S. Air Force (of which the author was a member from 1953 to 1957) bombed Mauna Loa to divert a lava flow and prevent it from reaching Hilo. The eruption ceased before the effectiveness of this tactic could be evaluated. Photo by J.D. Griggs, U.S.G.S.

Kilauea in Hawaii and Mt. St. Helens in the state of Washington are the volcanoes best known to most Americans. Many geologists have studied these two volcanoes; the U.S. Geological Survey (U.S.G.S.) has operated the Hawaiian Volcano Observatory on the rim of Kilauea caldera since 1912, and it established the Cascades Volcano Observatory at Vancouver, Washington in 1982, two years after the major eruption of Mt. St. Helens.

Kilauea and Mt. St. Helens exemplify two distinctly different modes of origin and eruptive behaviors. The former results from a hot spot in the earth's mantle, and the latter is the product of subduction of oceanic crust into the mantle. The exhibit Inside Active Volcanoes, at the Natural History Museum until February 28, focuses on these two volcanoes and their workings.

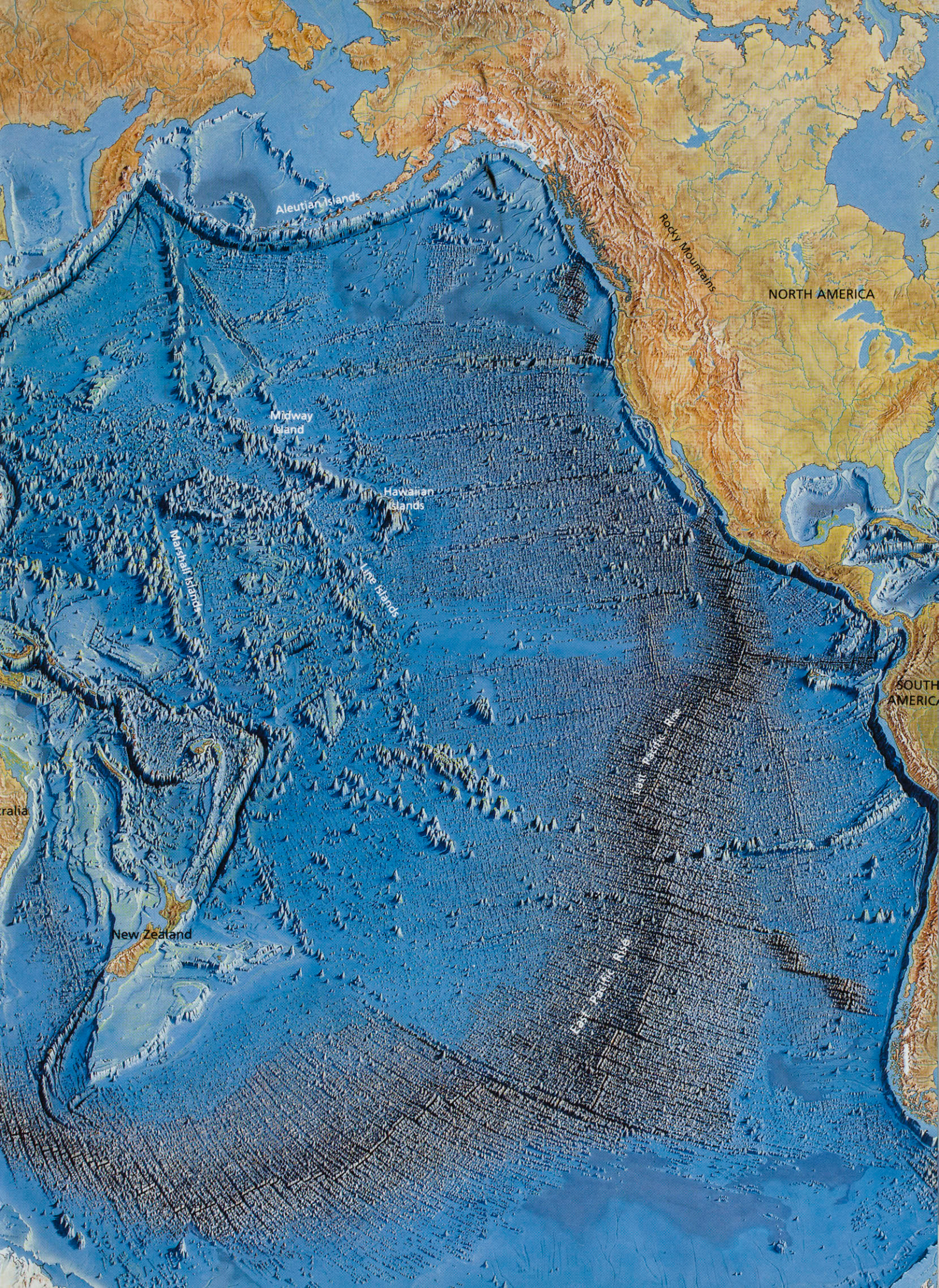
Although Kilauea has erupted almost continuously since January 1983, it is relatively quiet and approachable, and millions of tourists have witnessed its activity close up. It is the youngest of five volcanic centers on the Big Island of Hawaii, three of which have been active historically. The other currently active volcano on the Big Island is Mauna Loa, which rises about 53,000 meters (33,000 feet) above the ocean floor. It is the largest mountain on Earth (Mt. Everest is the highest). Kilauea and Mauna Loa have erupted on average every few years since at least 1820, before which detailed records are sketchy. Although there is little danger to human life from the eruptions of Hawaiian volcanoes, their fast-flowing, low-viscosity lavas can travel for many miles and pose a threat to villages and towns. Kilauea has recently destroyed many houses on the Hilo coast, and flows from the 1984 eruption of Mauna Loa came within about five miles of Hilo.

The current phase of eruptions of Kilauea, which began in January of 1983, is the longest more-or-less continuous eruption on Hawaii since 1924, before which Kilauea was nearly continuously active for more than a century. Mauna Loa erupted ceaselessly from 1872 to 1877. There is no indication that activity on Hawaii is decreasing; in fact, the volume of lava extruded during the past 30 years appears to be about five times the average for the 70-million-year history of the entire Emperor-Hawaiian chain.

In stark contrast, Mt. St. Helens is more episodic. During the 123 years before the May 1980 eruption, a violent and catastrophic blast that killed about 60 people, there was no observable volcanic activity. This violent mode of eruption is characteristic of most of the volcanoes on the Pacific Rim — the so-called Ring of Fire — including well-known Krakatoa in Indonesia and Katmai in Alaska. There were minor eruptions of Mt. St. Helens, possibly accompanied by some lava flows, in 1857, and another major eruption in 1800, which itself followed a quiescent period of 150 years. The sixteenth century appears to have been another static interval; this episodic activity appears to have characterized Mt. St. Helens since its formation. These Pacific Rim volcanoes erupt in short-lived but very energetic episodes, but their long-term energy outputs do not differ significantly from those of the Hawaiian type.

According to the eruptive history of Mt. St. Helens compiled by U.S.G.S. and university geologists over the past 30 years, the visible part of the volcanic cone is the youngest of the major Cascade mountains, having formed during the last 2,500 years — making it a geologic infant. However, some of the Mt. St. Helens ash is at least 40,000 years old, and U.S.G.S. geologists have recognized nine periods of pre-1980 activity, each lasting up to 5,000 years and separated by intervals of 200 to 15,000 years.

The concept of plate tectonics provides an answer to why the Hawaiian volcanoes behave so differently from their cousins on continents and continental margins. The deep-seated layers of the earth's mantle are hotter than the layers near the surface. This is largely the result of the decay of radioactive potassium, uranium, and thorium, together with residual internal heat remaining from the primordial accretion of the earth 4.5 billion years ago. Because this hotter material is less dense, it rises toward the surface and cools as it spreads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New Zealand

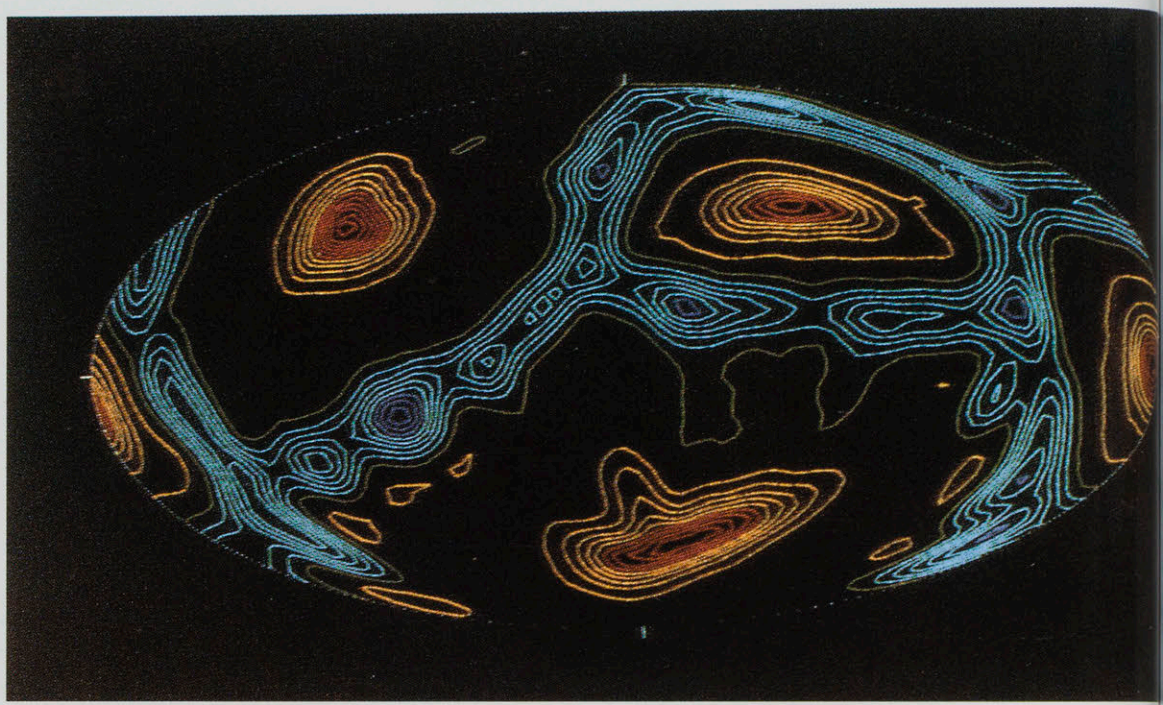
Gas-and-ash eruption of Mt. St. Helens seen from Harry's Ridge, 9 kilometers (5 miles) north, on April 6, 1983. Photo by Lyn Topinka, U.S.G.S.

Mt. St. Helens, July 22, 1980. Most of the original summit was removed in the violent May 18 eruption. Photo by Michael P. Doukas, U.S.G.S.

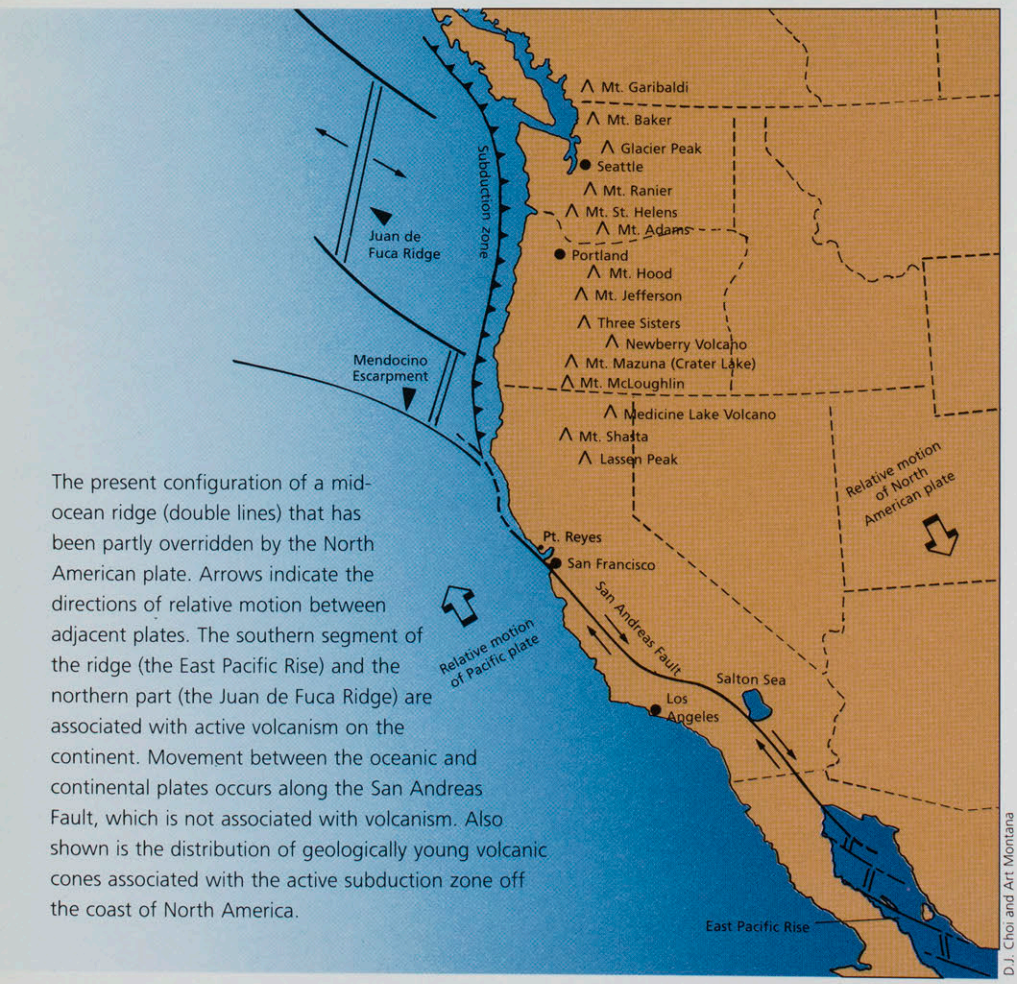
laterally. This cooler material then sinks, creating convection currents similar to those in your morning cup of coffee or in soup in a hot saucepan. This circulation is very slow — inches per year — because the mantle of the earth is largely solid, unlike your soup or coffee. In geologic time, however, this movement is significant, being responsible for volcanoes and earthquakes, and the drifting of continents.

Professor Jerry Schubert of U.C.L.A. has used computers to simulate the geometry of this three-dimensional convection, providing new insight into long-standing problems such as why volcanoes are located where they are. Schubert's model (see page 10) shows the hot, upwardly moving limbs of these convection cells are roughly cylindrical columns that produce "hot spots" where they intersect the surface of the earth. Geologists have postulated as many as 40 hot spots based on the measurement of heat flow at the land surface and on the ocean floors. Important examples of ocean islands that form from the magmas at hot spots include Iceland, the Galapagos Islands, the Azores Islands, and, most importantly because of the size and persistence of its hot spot, Hawaii.

Since the concept of plate tectonics emerged about 25 years ago, it has been generally accepted that the sinking, cooler limbs of the convection cells are expressed at the surface of the ocean floor as long, linear features such as subduction zones where light, thick continental plates override dense, thin oceanic plates — for example along the west coast of South America and within the convexity south of the Aleutian Arc (see map, page 7). Schubert's model is consistent with this. Traditionally, geologists have considered the rising, hot limbs of the convection cells to be coincident with the 40,000 kilometers- (25,000-mile) long system of mid-ocean ridges, along which new ocean floor is created by the outpouring and spreading of lava; most introductory textbooks in geology and geophysics portray mid-ocean ridges in this manner (see Figure A, page 11). However, I and many other geologists and geophysicists now question whether the mid-ocean ridges are directly associated with the rising limbs of the convection cells. Rather, we believe that these ridges are more passive features, occurring where magma from the mantle rises through tension fractures — features that result when the oceanic crust is pulled apart by subduction at each end (See Figure B on page 11). This concept is consistent with the geometry of Schubert's model in which the rising limbs of the cells are columnar plumes, not the long, linear features previously called upon to explain the system of ocean ridges. It is also consistent with early proposals by Professors J.Tuzo Wilson of Toronto and



Computerized simulation of convection in a sphere, showing only the surface of the earth in an egg-shaped, equal-area projection. The red, circular features are the hot spots, perhaps 160 kilometers (100 miles) in diameter, where the hot, rising, columnar mantle plumes intersect the earth's surface. The blue, linear features are the cooled mantle descending (subducting) into the mantle. For this model, it was assumed that half of the heat source is at the base of the convection cell and half within the cell, which is a reasonable model for Earth. From Bercovici, Schubert, and Glatzmaier, 1989.




The present configuration of a mid-ocean ridge (double lines) that has been partly overridden by the North American plate. Arrows indicate the directions of relative motion between adjacent plates. The southern segment of the ridge (the East Pacific Rise) and the northern part (the Juan de Fuca Ridge) are associated with active volcanism on the continent. Movement between the oceanic and continental plates occurs along the San Andreas Fault, which is not associated with volcanism. Also shown is the distribution of geologically young volcanic cones associated with the active subduction zone off the coast of North America.

W.J. Morgan of Princeton that many ocean-island volcanic centers, rather than ocean ridges, are perched above rising mantle plumes.

We can examine the origin of Kilauea- and Mt. St. Helens-type volcanoes within the framework of these concepts. The surface expressions of the convection cells, where the motions are largely horizontal, divide the earth's surface into about 12 major regions called tectonic plates — some continental and some oceanic. Hawaii is near the center of the Pacific plate, unlike most of the other 400 active Pacific volcanoes that are on the rim or Ring of Fire. Hawaii's unusual placement prompted Professor Wilson in the 1970s to propose a novel origin for the islands that is as accepted now as it was controversial then. On a standard map, one sees a line of islands stretching northwest from Hawaii (the Big Island) on one end to Midway on the other. A view of the oceanic floor (see page 7) reveals the rest of this chain — submerged islands and seamounts stretching up to the Aleutian Islands, with a bend north of Midway. It is now well established that the ages of these features increase from Hawaii northward, ranging from currently active on the Big Island to about 40 million years at Midway and about 70 million years near Alaska. Wilson proposed that there is a hot spot in the mantle that has remained at the present position of the Big Island for at least 70 million years. As convection in the mantle pushes the Pacific plate northerly, magma rises through the crust, creating a string of islands and seamounts in its wake. Seventy

A small gas-and-ash plume arises from Mt. St. Helens in 1982. Photo by Lyn Topinka, U.S.G.S.

million years ago, the northern end of this chain was at the present position of Hawaii. Forty million years ago, Midway occupied this spot, and there was a concomitant change in plate motion at that time, giving rise to the bend in the chain. The illustration on page 7 reveals similar geometry in other Pacific islands. For example, the Marshall, Gilbert, and Ellice Islands form a similar chain, aging northward, as do the Line Islands.

This configuration holds for the main Hawaiian Islands — the oldest being Kauai and the youngest being the Big Island — as well as for volcanoes on the individual islands. On the Big Island, for example, Kohala, the oldest, is on the northwest coast. Moving southeastward, we encounter Mauna Kea, which last erupted 6,000 years ago, then Hualali, which last erupted in 1801. Finally, we come to the active Mauna Loa and Kilauea volcanoes on the southeast coast. A new volcano, Loihi, is erupting 5,600 meters (3,500 feet) below sea level just off the southeastern coast of the Big Island; thus, five million years ago, Kauai was the only Hawaiian island, and continuing activity on Loihi may add yet another.

To examine the origin of Mt. St. Helens using this same concept of convection in the earth's mantle, look at Figure B on page 11, where I have illustrated two volcanoes that we will refer to as Mt. St. Helens-type. Imagine this figure to be a cross-section through the Pacific basin looking northward, and the continent on the right side to be South America. The mid-ocean ridge — in this

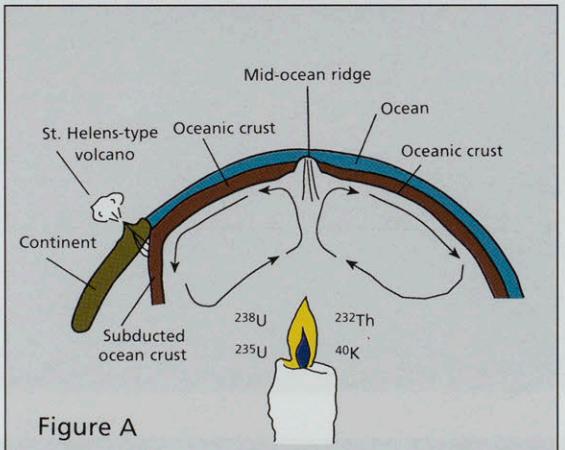



Figure A

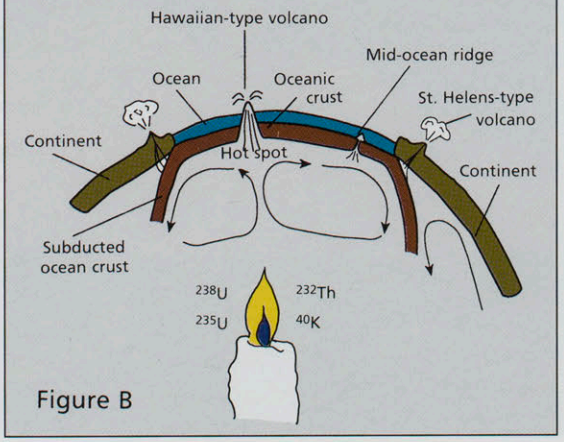



Figure B

Author's schematic cross-sections of the earth under the Pacific basin showing two ideas of how convection (represented by the circling arrows) in the mantle is driven by heat from the radioactive decay of Uranium 235 and 238, Thorium 232, and Potassium 40. In A, the *mid-ocean ridge* is a direct result of convection. It is shown as being a product of the upward-moving limb of the convection cells in the mantle, where the molten part of the rising mantle (the magma) penetrates the oceanic crust and creates new crust. The new oceanic crust spreads laterally on each side of the ridge because it is floating upon the underlying convection cell. B is similar to A, except that a *hot spot* sits atop the upward-moving limb, and the mid-ocean ridge is a more passive feature, occurring where magma rises through tension fractures. These fractures result when the oceanic crust subducts at both ends and pulls the crust apart. Here, the new crust originating at the mid-ocean ridge spreads laterally because the horizontal velocity of the subducting part of the plate is greater than that of the top of the convection cell.

case, the East Pacific Rise — (visible in the illustration on page 7) lies off the coast of South America and trends north up the Sea of Cortez toward the Salton Sea in southern California. It reenters the Pacific Ocean just north of San Francisco at Pt. Reyes. (The segment of this ridge between the Salton Sea and Pt. Reyes is on land rather than on the oceanic floor and is not a ridge, but rather the San Andreas Fault, which we will consider later.) The new ocean-floor slabs continuously created at this mid-ocean ridge are covered by the Pacific Ocean. Consequently, as they spread laterally, they become hydrated by chemically reacting with the overlying ocean water as well as with hot aqueous solutions rising from the magmas cooling beneath the ridge. That part of the new ocean floor east of the ridge spreads eastward until it eventually collides with the thicker, more buoyant continent. Be-

OPPOSITE TOP

Fountain with tephra plume at Pu'u 'O'o, 1984. Pu'u 'O'o produces this sort of powerfully spewing plume when volcanic gases under pressure from magma erupt as the pressure is released. Photo by C.C. Heliker, U.S. Geological Survey.

OPPOSITE BELOW

Low artesian-type fountain at Mauna Ulu, 1970. Mauna Ulu is a vent on the flank of Kilauea. Photo by Jeffrey B. Judd, U.S. Geological Survey.

Lava tube, Mauna Ulu eruption, 1969-71. Lava in these tubes can flow underground all the way to the coast. Photo by Jeffrey B. Judd, U.S.G.S.

Fountain of Pu'u 'O'o, 1984. Pu'u 'O'o is a cinder cone on the flanks of Kilauea volcano. A cinder cone builds up over time as magma that is ejected from the vent cools and solidifies before it lands. Photo by J.D. Griggs, U.S. Geological Survey.

cause the ocean-floor plate is denser, it sinks (subducts) beneath the continent, perhaps to depths of 640 kilometers (400 miles). However, when it reaches depths of 110 to 240 kilometers (70 to 150 miles) beneath the surface of the continent, the high temperatures and pressures in the mantle at this depth force most of this chemically combined water out of this subducted slab, and this released water causes partial melting of the slab or the overlying mantle. The water readily dissolves in the resulting magma, which rises through the continent and erupts, not uncommonly in violent explosions. Thus, the violent nature of the eruptions of these types of volcanoes is ascribable to their high content of water, carbon dioxide, and other volatile compounds, and the process can be likened to the uncapping of a warm beer. As the cap is removed, pressure is released and the carbon dioxide forms bubbles that can froth with vigor. Similarly, as the volatile-rich magma rises through the continental crust, pressure decreases, and the gases come out of solution, more or less violently, depending upon the geologic conditions. Thermodynamic calculations illustrate that the energy released by water exsolved from a magma can easily provide the total energy released in a Mt. St. Helens-type eruption.

In the case of Mt. St. Helens, moments prior to the May 18, 1980 eruption, an earthquake generated a huge avalanche of volcanic debris that removed the entire north flank of the summit. This in turn released pressure in the volcanic conduit, allowing the water, carbon dioxide, and other volatile components dissolved in the magma as well as that trapped in cracks and voids in the adjacent rocks to quickly expand, creating an explosion that destroyed nearly all plant and animal life over hundreds of square miles and an ash cloud that encircled the globe. These events are clearly displayed in the exhibit Inside Active Volcanoes.

If Mt. St. Helens results from subduction of the oceanic Pacific plate beneath the continental North American plate, then it is reasonable to ask if there are nearby volcanoes of similar origin. Anyone who has flown from California to Seattle will answer resoundingly "yes." As the illustration on page 10 clearly illustrates, there is a chain of about 15 volcanic cones extending from northern California to British Columbia, lying about 160 to 320 kilometers (100-200 miles) inland from the subduction zone just off the coast. A similar configuration occurs along the west coast of South America. A ready explanation for this arrangement of volcanoes is seen along the coasts of California, Oregon, Washington, and British Columbia, where hydrated oceanic crust is thrust under the continent along the active subduction zone. Because the angle of descent into the mantle is roughly 45°, and be-

Halemaumau Crater eruption, 1967. Halemaumau Crater is in the summit caldera of Kilauea. Kilauean eruptions are diverse; they can be explosive or passive, depending upon how much pressure from gases builds up in the magma. If magma is kept confined underground with no escape route for the gases, it can break to the surface and erupt violently. However, if much of the gas bubbling in a magma can escape, less pressure builds up, and it erupts passively. This is an example of non-explosive spatter eruptions at the same fissure. Photo by R.S. Fiske, U.S. Geological Survey.

cause the ocean floor begins to dehydrate at depths of 110 to 240 kilometers (70 to 150 miles), the resulting volcanoes are displaced eastward a similar distance from the subduction zone. The west coast of North America is a particularly revealing example of the relationship between the motion of plates and resulting volcanism.

When the North American plate overrode the central part of the mid-ocean ridge, it denied central and southern California the hazard of explosive volcanism and the majesty of mountains such as Shasta and Rainier. Instead, to accommodate motion between the North American and Pacific plates, our legacy is the San Andreas Fault. But the immense forces within the earth that create volcanoes never rest. Unknown to most southern Californians, there are young volcanoes nearby in the Mojave desert. I and my U.C.L.A. colleagues Mary Reid, Janet Leventhal, and Peter Holden have provided geochemical evidence that ocean floor lavas were thrust under southern California about 60-80 million years ago, providing the materials that much later melted to form these small volcanoes, excellent examples of which can be seen in the Cima volcanic field just east of the road between Baker and Kelso. My research suggests that the darkest colored cone and flows, almost devoid of vegetation, are younger than 1,000 years!

*Art Montana, an Emeritus Professor of Geochemistry at the University of California, Los Angeles, now resides near Pecos, New Mexico and works on environmental issues. While at U.C.L.A., he investigated volcanoes throughout the world and managed a laboratory where he and his students investigated chemical reactions at very high pressures to simulate conditions in planetary interiors.*

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# The Chinese Fossil Connection

## Interpreting the Origins of Humans and Apes

*by Jeffrey H. Schwartz*

Although often publicized as a discipline unto itself, the study of human origins is actually part of the broader study of *Homo sapiens* and the living apes, and their fossil relatives — an assemblage collectively referred to as the hominoid primates.

Apes and humans are hominoids, as are all their potential fossil relatives. Hominids are a subgroup of hominoids — members of our own species, *Homo sapiens*; or members of a fossil species of the genus *Homo*; or members of the extinct genus *Australopithecus*. We humans and our closest fossil relatives are hominid hominoids.

To study the evolution of a particular species of hominid, one has to make broad comparisons with other hominoids, especially the three living great apes: the African chimpanzee, the African gorilla, and the Asian orang-utan.

Interpretations of hominoid evolution have changed considerably over the decades. This was due in part to the reassessment of the relationships between *Homo sapiens* and living hominoids. Until the 1970s, the leading theory was that the great apes constituted a group to which humans are related. In the 1970s, the great ape group was dismantled, and only the African apes were thought to be closely related to humans. Then in the 1980s, it was suggested that only the chimp was closely related to humans.

But changes in interpretation of hominoid evolution also resulted from the discovery of new fossil specimens, and the reassessment of certain other fossils: are they related to humans or to apes? For example, some fossils were once seen as ancestral to specific apes, but now scholars are uncertain even about their general evolutionary relationship to hominoids. Other fossils were thought of as generic extinct apes but later re-interpreted as being ancestral to *Australopithecus*. Discoveries of more completely preserved specimens after the late 1970s actually reveal that these latter fossils most likely represent close relatives of the orang-utan.

Debates over the hominoid status of fossil primates continue, as do those over the relationships of agreed-upon hominoids to one another. One case revolves around some Chinese specimens. Though they have been interpreted as representing two species with different evolutionary lines, it seems increasingly clear that they constitute a single species of fossil hominoid. My recent analysis of the two best preserved skulls of this Chinese hominoid led me to the unexpected conclusion that underneath the facade of its strange facial skeleton lay a fossil relative of the orang-utan.

To understand the current state of affairs in the study of hominoid evolution, we must follow from the beginning the tortuous paths of interpretations and name changes imposed upon the fossils that are so crucial to the way we view hominoid evolution and, ultimately, human origins.

### FOR HUMANS AND EACH APE THERE IS AN ANCESTOR

As early as the mid-1800s, it was thought that certain European fossils from the Miocene epoch (approximately 5 to 25 million years ago), might represent an extinct ape and perhaps, as Thomas Huxley and others speculated, a distant ancestor of modern humans. The genus name given to the first specimen by its discoverer, Edouard Lartet, was *Dryopithecus*, which means "wood ape." In the years that followed the discovery of this specimen in France, additional finds of fossils supposedly related to *Dryopithecus* were made, first in the Siwalik Hills of Indo-Pakistan in the 1870s, and then in East Africa in the late 1920s. As was the practice in paleontology at that time, a new taxonomic name — not just a species, but often a new genus name — was attributed to each new discovery.

By the mid-1960s, a multitude of genera and species had come to be thought of collectively as the Miocene apes. In reference to the first genus named, *Dryopithecus*, this oddlot of purported fossil apes was typically placed within its own subfamily, Dryopithecinae (or, informally, the dryopithecines), within the family Pongidae (the pongids), which was the name applied until recently to the great apes (the Asian ape — orang-utan, and two African apes — chimpanzee and gorilla). Although there are current debates as to whether the chimp represents our closest living relative, it used to be thought — based on an 1863 essay by Thomas Huxley — that pongids were distantly related to humans, and fossil evidence of this common ancestry was sought among the dryopithecines. However, with so many potential dryopithecines to choose from, it was difficult to make sense of their evolutionary relationships, not only to pongids and hominids, but among each other.

A major resolution of this taxonomic chaos came in 1965 through the work of Elwyn Simons and his graduate student, David Pilbeam, at Yale University. In a seminal publication, Simons and Pilbeam reduced the number of dryopithecines to just a handful of separate genera. Among these, the most important dryopithecines were *Dryopithecus* from Europe, *Proconsul* from East Africa, *Sivapithecus* (named after the Hindu god, Siva) from Indo-Pakistan, and *Gigantopithecus* from

Opposite
Artist's reconstruction of (left to right) *Lufengpithecus* female, male, and female with offspring. Since the partial skulls and a few mandibles are the best preserved parts of the animal, the rest of the body was drawn to represent a generalized apelike animal. Although *Lufengpithecus* appears to have been related to a group that includes the orang-utan, it was probably not as specialized as the orang, which has exceedingly long arms and short legs. This reconstruction shows a modest elongation of the arm. The face is what makes *Lufengpithecus* distinctive among hominoids. The setting in which the animals are depicted is based on paleobotanical and paleoclimatological analyses from the same site. The primary plant growth in the meadow in the background is a version of knotweed. The two small bushes on the left are holly shrubs, the adjacent trees are multiforked silvery alders, and the large trees in the illustration are walnut and hickory. The hollies and alders are more moisture-dependent than the other trees. The forest also would have contained elms, sourgum trees, and wingnuts. The low vegetation near the animals includes walnut saplings and various species of ferns. Painting by Timothy D. Smith.

Indo-Pakistan as well as China. (*Gigantopithecus*, the largest fossil ape known, was younger than the Miocene apes; it came from Pliocene and Pleistocene deposits.)

These theories of dryopithecine relationships held sway for almost 25 years. Basically, the ancestry of each of the great apes was sought in a particular dryopithecine. A small and a large species of *Proconsul* were supposed to have given rise, respectively, to the chimp and the gorilla. The orang-utan, which is now restricted to the southeast Asian islands of Borneo and Sumatra, was supposed to have evolved from a species of *Sivapithecus*. Another species of *Sivapithecus* was supposed to have given rise to the Indo-Pakistani species of *Gigantopithecus*, which, in turn, was supposed to have given rise to the larger Chinese species of *Gigantopithecus*. According to the general scenario, *Dryopithecus* did not leave any known descendants.

In their revision of Dryopithecinae, Simons and Pilbeam reduced the taxonomic diversity further by excluding one particular Miocene genus, *Ramapithecus*, from the group, because Simons thought that this hominoid's relationships lay closer to humans than to apes. His belief was based on the doctoral dissertation research of G. Edward Lewis, a Yale graduate student working with the Indo-Pakistani fossils who had actually named *Ramapithecus* in the 1930s (after the Hindu god Rama). Features of *Ramapithecus*' jaw and teeth convinced Lewis that it was related to humans and not apes, but his suggestion fell by the wayside. Years later, Simons rediscovered the original specimen in a museum drawer, and in the early 1960s began to argue forcefully that *Ramapithecus* was indeed a hominid ancestor, evolved from a dryopithecine ancestor.

While the idea that the great apes could each be derived from a specific dryopithecine was generally accepted, Simons' arguments for hominid ancestry of *Ramapithecus* were received with less enthusiasm. As more complete specimens were discovered, *Ramapithecus*' supposedly human features were repudiated one by one; for example, its jaw shape turned out to be not appreciably different from that of extant apes and dryopithecines, and it was certainly not specifically human-like.

However, one complex of features, having to do with the molar teeth in particular, continued to support the association of *Ramapithecus* with hominids. The layer of enamel that capped *Ramapithecus*' molars was extraordinarily thick and, perhaps as a result, the occlusal or chewing surfaces were relatively flat and cusp definition blurred. The same was true of "proper" hominids, the species of *Homo* as well as of *Australopithecus*.

Once thick molar enamel and flat molar occlusal surfaces were thought to be definite hominid characters, no set of teeth was safe from scrutiny. Among fossils, it turned out that the dryopithecines *Sivapithecus* and *Gigantopithecus* had hominid molars, as did two more recently discovered Miocene hominoids, *Ouranopithecus*, from the Macedonian region of Greece, and *Rudapithecus*, from Hungary. As a result of these discoveries, Pilbeam and others suggested that, instead of *Ramapithecus* being the lone potential ancestor of proper hominids, there had been a group of hominoids with hominid molars, from which proper hominids had evolved. This group was made up of *Ramapithecus*, *Sivapithecus*, *Gigantopithecus*, *Ouranopithecus*, and *Rudapithecus*.

The thick molar enamel and flat occlusal surfaces contrasted sharply with the common configuration among extant apes, monkeys, and the fossils still thought of as dryopithecines: a thin layer of molar enamel with more surface definition and detail and more cusp delineation. There were, however, a few exceptions even to this precept: the orang-utan and one species each of Old and New World monkey had thick, not thin, molar enamel. And the occlusal surfaces of an orang's molars were definitely flat, not well-delineated. By the time this was discovered, in the 1970s, only the African great apes were thought to be closely related to hominids. Thus, the orang's thick molar enamel was interpreted as having evolved in parallel with the thick molar enamel of the *Ramapithecus* group and proper hominids.

By the time the 1970s drew to a close, the picture of hominoid evolution had changed considerably. Instead of seeking hominid ancestry in *Ramapithecus* alone, there was now a "thick molar-enamelled" group, from which the ancestry of proper hominids was still sought — but in more general terms. Because *Sivapithecus* was shifted into this group of hominid ancestors, the orang lost its potential ancestor. Concurrently, interest in seeking the ancestry of the African apes in *Proconsul* began to die out.

## AND THEN THERE WERE NO HOMINID ANCESTORS

BUT THE IDEA THAT HOMINIDS were derived from a Miocene thick-molar-enamelled hominoid was not destined to be long-lived either. In the late 1970s, Peter Andrews of the Natural History Museum in London, and a Turkish colleague of his, Ibrahim Tekkaya, shook things up with their discovery of new specimens of *Sivapithecus* from the late Miocene (circa 8 million years ago)

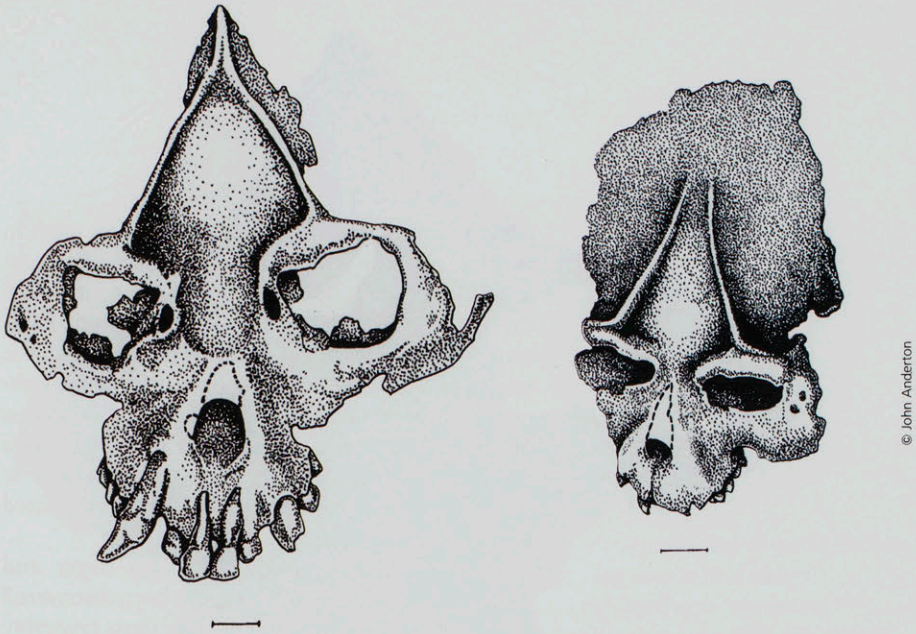
of Turkey. In their 1980 article on the new *Sivapithecus* specimens, Andrews and Tekkaya made two important points. First, they argued convincingly that *Sivapithecus* and *Ramapithecus* were actually the same animal. As such, *Sivapithecus* was the genus name of choice because it had what taxonomists call "priority" over *Ramapithecus*. (*Sivapithecus* had been named in 1910 by British paleontologist Guy Pilgrim, decades earlier than *Ramapithecus*.) Thus, the number of genera in the group from which proper hominids were supposed to have evolved was reduced by one.

This suggestion wasn't too difficult to embrace. It was the second part of Andrews' and Tekkaya's article that was astonishing.

One of the specimens they had found consisted of the upper jaw (teeth and palate) and most of the lower face (from the lower rim of the bony eye socket or orbital regions on down). This was the first glimpse ever of a *Sivapithecus* face, even if it was only the lower part of the face. But instead of displaying features characteristic of a hominid, this partial face was blatantly orang-utan-like in a surprising number of bony details. Then, in 1982, David Pilbeam announced the discovery in late Miocene deposits of Indo-Pakistan of an even more completely preserved specimen of *Sivapithecus*, represented by a lower jaw, the face from the upper jaw to the forehead, and even some pieces of the braincase. *Sivapithecus* (including the used-to-be *Ramapithecus*) was not, after all, related to hominids. Instead, it was very obviously related to the orang.

A short-lived phenomenon arising from subsuming *Ramapithecus* in *Sivapithecus* and making the two equivalent was that all thick molar-enamelled Miocene hominoids were thought of as species of *Sivapithecus*. Since the original *Sivapithecus* seemed to be orang-related, so was, it seemed, the new, expanded *Sivapithecus*. By default, the relationships of *Gigantopithecus* were also assumed to lie with the orang group.

If these thick molar-enamelled hominoids were not related to humans, then thick molar enamel was not an evolutionarily significant feature after all. Since chimps and gorillas, with their thinly enamelled molars, were thought to be more closely related to hominids than the orang, the phenomenon of thin versus thick molar enamel within hominoids had to be explained. And it was, thusly: thick molar enamel must have characterized the last common ancestor of all large-bodied hominoids; two groups (an *Australopithecus/Homo* group and an orang/*Sivapithecus* group) retained this ancestral condition while a third group (a chimp-gorilla group) re-evolved thin molar enamel.



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Artist's reconstruction of the male (left) and female skulls of *Lufengpithecus*. When the cracks are eliminated, the details of face, tooth, and skull are even more apparent. The holes on the outer side of the orbit for passage of vessels are only clearly preserved on the right side of the male specimen and the left side of the female, but it is safe to assume that similar perforations existed on the missing orbits. The nasal aperture clearly would have been small in both specimens. The scale below each specimen represents one centimeter.

With thick molar enamel no longer seen as something that reflected the relation of specific hominoids to one another, a different kind of debate arose. Maybe some of those fossils that had become lumped with *Sivapithecus* were really not related to the orang. Maybe there still could be a hominid ancestor lurking in the collection of Miocene fossil hominoids. Soon, the genus names that had been collapsed into *Sivapithecus* in the wake of Andrews and Tekkaya began to reappear in the scientific literature. French paleontologist Louis de Bonis, the discoverer of *Ouranopithecus*, jumped in and argued that his hominoid had a direct link to hominids because of similarities of the lower premolar shared with Don Johanson's "Lucy," *Australopithecus afarensis*. The genus *Rudapithecus* was also briefly resurrected.

But while the center stage in the synonomizing of names and the shuffling of theories was commanded by the Indo-European fossils, a similar but quieter process of discovery, interpretation, and reinterpretation had been going on in China, with what have come to be regarded as some of the most extraordinary of hominoid fossils.

## ENTER THE PLAYERS FROM CHINA

RELEVANT TO THE LARGER SAGA OF hominoid evolution is work that began in the 1970s in the southern Chinese province of Yunnan, at a site in Lufeng county. The site is late Miocene in age, approximately the same age as the sites in Turkey and Indo-Pakistan that yielded the faces of *Sivapithecus*.

In 1976, members of a joint field team of paleontologists from the Institute of Vertebrate Paleontology and Paleoanthropology of the Chinese Academy of Sciences in Beijing and the Yunnan Provincial Museum made the first important discovery in the lignite deposits that characterize the Lufeng site. They found an almost complete man-

dible or lower jaw, with virtually all of its teeth in pristine condition. The paleontologists who published a description of this specimen in 1978 thought it was the most hominid-like of any Miocene hominoid — in the shape of its mandible, the size of its lower incisors, the breadth and smoothness of the sides of its molars, and the configuration of the two cusps of its first lower premolar. Since *Ramapithecus* was at the time still regarded as a Miocene hominid, this specimen was named *Ramapithecus lufengensis*.

A second lower jaw, much larger and more robust than the first, had also been discovered in 1976. It was thought to compare most favorably among fossil hominoids with *Sivapithecus*, particularly in aspects of mandibular, anterior tooth, and molar shape. This new Chinese hominoid was placed in its own species, *Sivapithecus yunnanensis*.

But the Chinese specimen differed from Indo-Pakistani *Sivapithecus* in two distinctive ways: a region of muscle attachment on the inner surface of the mandible was wider and flatter, and the enamel of the occlusal surfaces of the molars was not smooth but wrinkled. In the latter feature, the Chinese specimen's teeth resembled those of recent orangs as well as fossil orangs half a million to a million years old. Perhaps, the authors speculated, the Chinese specimen represented a "link" from the late Miocene, via Pleistocene fossil orangs, to the modern orang-utan.

The importance of the Lufeng site was further affirmed by the discovery in 1978 of a partial skull that seemed to be that of *Sivapithecus yunnanensis*. The top of the braincase, the entire face, and most of the upper jaw and teeth were preserved. However, due to the whims of fossilization, especially in lignite deposits, the specimen had been crushed so that the top of the braincase was deflected upward and the entire specimen was riddled with cracks. The brittleness of the specimen made reconstruction a next to impossible task.

Three years later, a relatively complete skull was found that was attributed to *Ramapithecus lufengensis*. Most of the braincase, the base of the skull, the face and upper jaw, and some teeth were preserved. As with the other partial skull, this one had been crushed during fossilization, but most of the important regions were still analyzable. In overall dimensions, this specimen was markedly smaller than the partial skull referred to *Sivapithecus yunnanensis*. Although hundreds of teeth and jaw fragments, as well as other specimens of parts of skulls were also uncovered, these two skulls and the original lower jaws remain the most anatomically informative specimens.

In the first published description, the larger Lufeng hominoid, *Sivapithecus yunnanensis*, was compared only with a skull of an orang-utan, a partial skull of the East African fossil hominoid *Proconsul*, and an almost complete skull of the largest and most robust species of *Australopithecus*, *Australopithecus boisei*. The four compared favorably in their lack of large brow ridges above their orbits (chimpanzees and gorillas, for instance, develop large brow ridges that protrude up and out from the upper margins of their orbits). They were also similar in having broad cheek bones, and thus broad faces. And the Lufeng *Sivapithecus* and the orang were even further alike in their upper incisors. Instead of being morphologically similar to one another — as these teeth are, for instance, in humans — the first and second upper incisors of the Lufeng *Sivapithecus* and the orang differed in size and shape. The first upper incisor was large, broad, and spatulate, with a long, straight cutting edge — very much like our own first upper incisor, but broader — while the second upper incisor was puny and more conical in shape.

Because of the similarities among the four hominoids compared, the authors concluded that *Sivapithecus yunnanensis* had played many evolutionary roles. It was ancestral to the orang, it was a link between the orang and *Proconsul*, and it was related, somehow, to *Australopithecus boisei*.

The first publication on the smaller skull, which had been attributed to *Ramapithecus lufengensis*, was less detailed and interpretative. The report was essentially an announcement of the discovery. Speculation about the role of *Ramapithecus* in general, and the Lufeng *Ramapithecus* in particular, was minimal.

On the heels of these articles Wu Rukang, one of the senior paleontologists in Beijing, and two colleagues, Xu Qinghu and Lu Qingwu, came out with a major article in which they rejected the notion that two different large-bodied hominoids were present in the fossil assemblage from Lufeng. Rather, Wu and his colleagues concluded that the larger *Sivapithecus yunnanensis* and the markedly smaller *Ramapithecus lufengensis* represented, respectively, male and female members of the same species. Instead of species differences, the Lufeng hominoids were displaying sex-related differences, that is, differences due to sexual dimorphism.

The justification for this interpretation is that, if you strip away size, and control for certain features that are size-related, the specimens are essentially the same in details of skull, jaw, and teeth. Present-day analogies can be found in male and female gorillas as well as male and female orang-utans. In these extant large-bodied hominoids, males can approach (and in orangs sometimes even exceed) twice the size of females. But not only are male gorillas and orangs much larger than females,

they have certain features not typically seen in females, such as massive bony crests on their skulls for the attachment of large muscles. If, however, you account for size and size-related features, such as the crests, males and females are morphologically similar in the details specific to their species.

One of the odd features of each Lufeng skull was the breadth and concaveness of the region separating the orbits. In other hominoids, as well as in monkeys, this region between the eyes is either flat or swollen. The two Lufeng skulls also bore two distinctive muscle scars (a right and a left) along the length of the top of the skull. These scars took the form of thick, raised ridges, of the sort that one sees only on occasion in the largest of male gorillas and orangs. Each ridge took origin from above the outermost part of the upper margin of the orbit. The ridge then coursed inward a bit, following the upper margin of the orbit, before it veered off, almost at an angle, to course along the top of the braincase. In the larger skull, right and left ridges eventually met in the midline and coalesced into a single crest, as the typically less pronounced muscle scars of male orangs and gorillas do. In the smaller skull, the ridges coursed toward the midline, but remained apart, as the less distinctive muscle scars of female orangs and gorillas do.

The large and small Lufeng specimens also differed in canine size and shape in the same ways in which male and female apes do. The upper and lower canines of the larger Lufeng hominoid were large and stout. The smaller skull had lost its canines during fossilization but the preserved sockets would not have held stout teeth. The lower canines of the smaller mandible were present and noticeably smaller and slenderer than their counterparts in the mandible of the larger Lufeng hominoid.

If, as Wu, Xu, and Lu suggested, the skulls that had been placed, respectively, in *Sivapithecus yunnanensis* and *Ramapithecus lufengensis* were really male and female representatives of the same species, then the proper name for all of them was *Sivapithecus yunnanensis* since *Sivapithecus* as a taxonomic name had priority over *Ramapithecus*. Because of the shape and wrinkling of the enamel of the molar teeth and the great size disparity between upper first and second incisors in the male skull — as well as because of Andrews and Tekkaya's and Pilbeam's reinterpretations of the relationships of their species of *Sivapithecus* — Wu, Xu, and Lu maintained that *Sivapithecus yunnanensis* was not only related to the orang, but that it had probably been the ancestor of the present-day orang.

But lumping together into the same species specimens of such disparate size brought its own problems. During the next few years, Wu and

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Frontal view of partial cranium believed to be a male *Lufengpithecus lufengensis*. Although the specimen was severely crushed, as evidenced by the web-like pattern of fine cracks on the surface, the relative shapes and positions of teeth and cranial bones are still easily studied. For instance, the raised rim of the oddly squared orbits, or bony eye regions, the interorbital depression (the sunken area between the eyes), the stout ridges converging into a sagittal crest along the top of the skull (for attachment of the temporal muscles), and the disparity in size and shape between the front two teeth and the two teeth flanking them, are easily seen. Features of the orbit and teeth link *Lufengpithecus* with *Sivapithecus* and the orang. The specimen is housed at the Institute of Vertebrate Paleontology and Paleoanthropology of the Academia Sinica in Beijing.

Jeffrey Schwartz

Oblique view from above of the partial cranium believed to be a female *Lufengpithecus lufengensis*. Although it too is severely cracked, the specimen preserves many important details of the top of the skull and especially of the face that are similar to those on the larger skull. This view clearly illustrates the flattened cheek bone region, another feature that appears to link *Lufengpithecus* with *Sivapithecus* and the orang.

Jeffrey Schwartz

Frontal and side views of skulls, clockwise from top left, gorilla, human, orang-utan, and chimpanzee. Among these four hominoids, the orang stands out as having rimmed orbits, vertical and flattened cheekbones, large holes through its outer orbits above their lower margins, small nasal aperture, and marked disparity in size and shape of the incisors. These are unique features the orang shares with *Lufengpithecus* and *Sivapithecus*.

Charles Oxnard, the master of morphometric analysis who is Director of the Centre for Human Biology at the University of Western Australia, published a series of articles in which they tried various statistical analyses of measurements they had taken on the hundreds of teeth that, together with the better preserved mandibles and skulls, Wu had placed in *Sivapithecus yunnanensis*. When compared to the most sexually dimorphic of primates — gorillas and orangs — the degree of variation within the Lufeng sample far exceeded the extremes of the males and females of these extant species. For those paleoanthropologists who use the present as the ultimate test of the past, there remains the specter of doubt about the reality of putting such large and small specimens into the same species — even if the specimens look like large and small (that is, male and female) versions of the same animal. However, there is no *a priori* reason why extinct species cannot exceed the extremes of sexual dimorphism exhibited by extant species. And the first example of this among hominoids would thus be the Lufeng hominoid.

## A NEW GENUS FOR THE LUFENG HOMINOID

In spite of some residual doubt about the species' extremes of sexual dimorphism, *Sivapithecus yunnanensis* became accepted in the scientific literature. The problem, however, was that this Chinese version of *Sivapithecus* did not conform to the same suite of similarities, especially in aspects of cranial, facial, and palatal morphology, that characterized the Turkish and Indo-Pakistani species of *Sivapithecus*. In 1987, Wu Rukang addressed this issue by coining the genus name *Lufengpithecus* — "ape from the region of Lufeng." The species name for the new genus was *lufengensis*, because it had priority over *yunnanensis*. Thus *Lufengpithecus lufengensis* came into being.

In his argument for the recognition of *Lufengpithecus* as a genus distinct from *Sivapithecus*, Wu relied mostly on comparisons of the male Lufeng skull with the Turkish and Indo-Pakistani

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specimens. The reason for this was that the facial specimen from Turkey and the partial skull from Indo-Pakistan were also supposed to represent the males of their respective samples. Wu presented a list of six features in support of placing the Lufeng fossils in their own genus. Of these features, I think that some are more revealing than others in supporting the separation of *Lufengpithecus* from *Sivapithecus*.

A striking feature of *Lufengpithecus* is that it had a very broad face and broad palate. The Turkish and Indo-Pakistani *Sivapithecus* had a somewhat narrower face and a noticeably narrower and longer palate. Together with the broader face, the orbits of *Lufengpithecus* were broadly separated from one another across the region of the "bridge" of the nose, and, even more uniquely, this broad interorbital region was sunken. In contrast, the interorbital distance in *Sivapithecus* was so narrow that the inner margins of the orbits touched at the midline of the face. *Lufengpithecus* had very long, somewhat ovoid orbits that were oddly squared-off or angled in their upper outer margins. *Sivapithecus*, on the other hand, had tall, narrowly ovoid orbits.

Since many paleoanthropologists had already come to think of the Lufeng hominoid as something different from the Turkish and Indo-Pakistani *Sivapithecus*, there wasn't much resistance to accepting the new genus, *Lufengpithecus*. There has, however, been less unanimity about the evolutionary relationships of this hominoid. For instance, in yet another publication, Wu proposed a possible association of the Lufeng hominoid with the chimpanzee. Even before Wu coined the name *Lufengpithecus*, David Pilbeam and his student Jay Kelley co-authored the opinion that the Lufeng hominoid was closely related to neither the orang (as was Pilbeam's *Sivapithecus*) nor any living hominoid. Rather, they suggested, it was probably a distant relative of all extant large-bodied hominoids. More recently, Kelley, in collaboration with Dennis Etler, a doctoral student at the University of California, Berkeley, has more strongly argued that *Lufengpithecus* is a generalized hominoid with no special relationship to the orang or any extant hominoid.

## WILL THE REAL ORANG RELATIVES PLEASE STAND UP?

WHEN, IN 1988, I HAD THE OPPORtunity to study the large and small skulls and mandibles attributed to *Lufengpithecus*, I was immediately impressed by how odd and uniquely different in many ways this hominoid is from other living and fossil hominoids. Perhaps the most arresting feature of this hominoid is the broad, and definitely sunken or depressed, interorbital region. Some paleontologists had suggested that the region had been depressed during fossilization. Having been fooled more than once by fossil material that had been crushed or warped through this process, I was particularly aware of that possibility. To be sure, there was a myriad of fine cracks across the bony surfaces of the skulls, but it was still possible to tell that the sunken interorbital region had not been artificially deformed. Moreover, the region was sunken in exactly the same way in both skulls.

It was important to verify the true configuration of the interorbital region because then I could analyze with confidence the margins of the orbits. Instead of just coming to an edge, the orbits of the Lufeng specimens bore a low-mounded bony rim around their inner and upper margins as well as partially along the outer portions. Although this particular feature had not been described previously, I knew it would be relevant to comparisons with *Sivapithecus* and the orang. I also noticed that there were two large holes (through which nerves and blood vessels had once coursed) where the outer orbital rim merges with the cheekbone; these holes were located well above the level of the lower rim of the orbit. They were clearly visible on the right side of the large skull, but crushing and infilling with lignitic matrix obscured the detail on the left side—there was only the slightest indication that they had been present. On the smaller Lufeng skull, I found these two large holes preserved on the left side; the right cheekbone and outer portion of the right orbit had been lost during fossilization.

While studying the Lufeng specimens I noted the features Wu Rukang and his colleagues had delineated as similarities between the *Lufengpithecus* and the orang. One of the most obvious was the disparity in size and shape between the upper first and second incisors: the first was large and spatulate while the second was much smaller and more conical. Another region of apparent similarity was in the length of the nasal bones and the shape and size of the aperture beneath them that opens into the internal nasal cavity. Although this region was slightly damaged in both Lufeng skulls, enough remained intact to allow for a plausible reconstruction of nasal bone length and nasal aperture shape and size. *Lufengpithecus* apparently had long nasal bones and a small, somewhat triangular nasal aperture, just like the orang.

Steve Ward of Kent State University, who had also studied the Lufeng material, is an expert on the facial anatomy of fossil hominoids, especially the development of air sinuses or cavities such as the ones we have within in our cheekbones (the maxillary sinuses) and in the bone beneath our eyebrows (the frontal sinuses). Not all primates develop facial sinuses, and among those that do, there are different patterns. For instance, among living primates, only humans and African apes develop frontal sinuses; orangs develop maxillary sinuses that extend up through the interorbital region and may even arch over the orbits, creating pseudo-frontal sinuses; and chimps develop maxillary sinuses that invade the hard, bony palate, creating something that looks like pita bread. Ward has found that various Miocene hominoids developed true frontal sinuses — they are huge in *Proconsul* — while *Lufengpithecus* and *Sivapithecus* had maxillary sinus expansion into the interorbital region, just like orangs.

Bit by bit, it began to become clear that

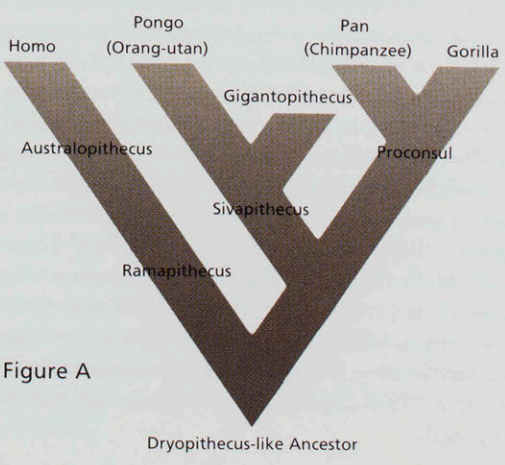


Figure A

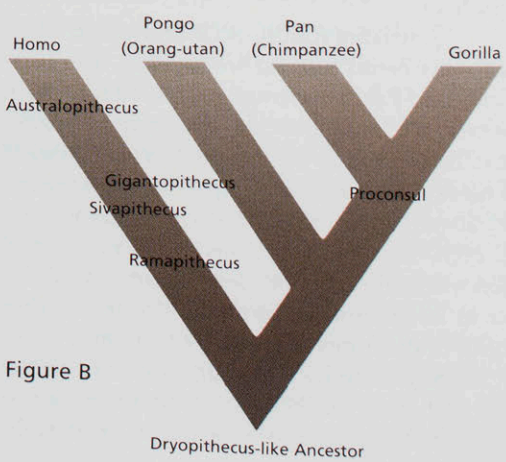


Figure B

Three diagrams showing theories of relationships of fossil and living hominoids. Figures A and B depict the idea that was popular until the end of the 1960s: that the three great apes constitute a group to which humans are ultimately related. In Figure A, which was widely accepted during the 1960s, *Ramapithecus* was linked to proper hominids by virtue of its low-cusped cheek teeth and thick molar enamel; the Asian *Sivapithecus* and *Gigantopithecus* were thought to be related to the Asian orang. In Figure B, the discovery of thick molar enamel in *Sivapithecus* and *Gigantopithecus* resulted in these hominoids being lumped with *Ramapithecus* to form a larger group, from which hominids were supposed to have evolved. Figure C depicts the 1970s theory that only the African great apes are closely related to hominids. Asian hominoids were then re-associated with the orang, because new fossils of *Sivapithecus* demonstrated that, in spite of having "hominid" molars, this hominoid possessed many facial features otherwise seen in the orang.

*Lufengpithecus* was probably not just a generalized hominoid that was distantly related to all other large-bodied hominoids. Instead, you could actually put your finger on features that might link *Lufengpithecus* with other hominoids. The curious thing, though, was that some of *Lufengpithecus*' features were the same as those that had been used to argue for a close evolutionary relationship between *Sivapithecus* and the orang.

Among living hominoids, the orang has many unique features. Some of those present in the skull and teeth include: tall and narrowly ovoid orbits rimmed by a low mound of bone and set so close to one another that their inner margins often meld together; multiple large holes (for nerves and arteries) outside the outer orbital rims and above the lower margin of the orbit; long nasal bones; a small, triangular nasal aperture; maxillary sinuses extending up into the interorbital region; and dissimilarity between upper first and second incisors. When the Turkish and Indo-Pakistani *Sivapithecus* faces were found to have these, as well as other, orang features, Andrews and Tekkaya and Pilbeam had good reason to conclude that *Sivapithecus* was closely related to the orang.

But now there is *Lufengpithecus* to contend with. With its very broad face, broadly ovoid (but "cornered") orbits, short and broad palate, broad and depressed interorbital region, and distinct cranial crests, this hominoid certainly gives the impression of being unlike other hominoids, and, thus, perhaps, only distantly related to them. However, *Lufengpithecus* also possesses features otherwise shared by *Sivapithecus* and the orang: rimmed orbits; upwardly expanded maxillary sinuses; upper incisor dissimilarity; long nasal bones; small, triangular nasal aperture; and multiple, large holes outside the outer rim and above the level of the lower rim of the orbit. Perhaps, then, if these features are truly reflective of evolutionary relatedness, they reflect a relationship among *Lufengpithecus*, *Sivapithecus*, and the orang. Within this group, the latter two still emerge as the most closely related because they share certain features possessed by neither *Lufengpithecus* nor other hominoids.

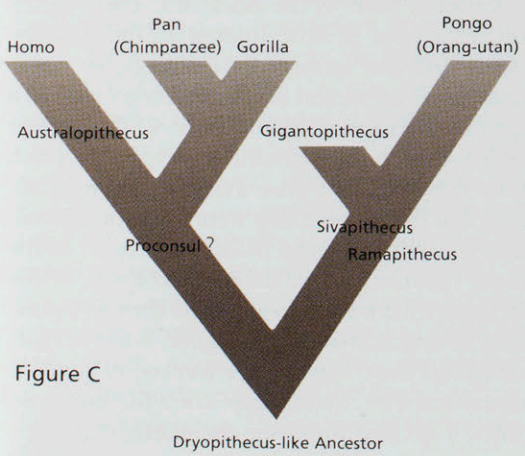

Figure C

In an article published several years ago I also suggested that *Ouranopithecus*, from the Macedonian region of Greece, and *Rudapithecus*, from Hungary, might also be part of an orang group, but not as closely related to the orang as *Sivapithecus* or even *Lufengpithecus*. According to Steve Ward, *Ouranopithecus* and *Rudapithecus* have upwardly expanded maxillary sinuses. Of these two hominoids, I think that *Ouranopithecus* may be more closely related to the *Lufengpithecus* — *Sivapithecus* — orang group because, in addition to other *Sivapithecus* — orang features, its upper incisors are also dissimilar in size and shape.

Although some colleagues still maintain that *Rudapithecus* is a dryopithecine, there is not as much resistance to the suggestion that *Lufengpithecus* and even *Ouranopithecus* might be related to *Sivapithecus* and the orang. The relationships of *Gigantopithecus* will remain even more difficult to assess until we know more about this largest of all hominoids than just its lower jaw and isolated upper teeth. The general assumption is that it might also be part of the orang group.

These suggestions, as with any other evolutionary hypothesis, will, of course, have to be subjected to further analysis and testing. What is odd, though, about how the picture of hominoid evolution has changed is that most of the fossils that were at one time thought of as related to proper hominids now appear to be related to the orang. All of them, including the orang, have molar features that were defined as hominid. Interpretations of the evolutionary significance of these features may have changed for the time being, but the observations remain valid. It wouldn't surprise me a bit if, sometime in the near future, the picture of hominoid evolution were to be redrawn in totally unexpected ways.

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# An Ancient Ship in the Wine Dark Sea

*by Willard Bascom*

*Somewhere, far out beneath the wine-dark sea of Ulysses, there lies an ancient wooden ship. It sits upright on the bottom, lightly covered by the sea dust of twenty-five hundred years. The wave-smashed deck house and splintered bulwarks tell of the violence of its last struggle with the sea. A stub of mast still remains, but the tattered sails and frayed cordage decayed into dust before the first Crusade. A few ballast stones leak from the hole where a weak plank finally gave way to let in the sea and bring about the end. But the cargo and its containers, the weapons and tools and personal possessions of the crew, are still intact, neatly packaged in the wrecked hulk.*

*The ship was there when Imperial Rome's galleys controlled the seas, when the forces of Christendom battled the infidels hundreds of fathoms above it, when the pirates of Tripoli were stilled, and when Nazi submarines roamed unchecked.*

*The old ship has waited since long before the time of Christ in the quiet and blackness of the abyss. It sails unmoving down the fourth dimension to meet us at some point in destiny, bearing evidence of a culture unknown to any living man.*

WILLARD BASCOM
*Deep Water, Ancient Ships*
(Doubleday, 1976)

*More than one-tenth of all the ships that ever sailed eventually sank to the ocean bottom in depths far below the reach of divers; some thirty thousand of these ships went down before the Christian Era. When they are protected by deep, dark, quiet waters with low oxygen content, the wood and organic materials on board, which would disappear so quickly in shallow water or in humid terrestrial environments, may last for thousands of years. Willard Bascom believes that a vast archaeological treasure may lie beneath the deep waters of the Sea of Marmara and the Black Sea, in wrecks along once-heavily-traveled trade routes and at the sites of forgotten naval battles. He uses twentieth-century technology to find ancient ships such as these.*
THE EDITORS

Alinari/Art Resource, New York. A1.46973. Relief from sarcophagus depicting three ships. Copenhagen, NyCarlsberg Glyptothek.

THIS TALE BEGINS ON JANUARY 15, 1991 WITH A lunch between three oceanographers in a waterfront restaurant in San Pedro, California. I listened as my two associates, ex-submarine skippers Don Walsh and Don Keach, described their latest joint venture, a complex enterprise between their international diving company and various Soviet organizations (including the Academy of Sciences and the Merchant Marine).

The venture, Soyuz Marine, had been set up mainly to provide diving and ship-bottom-cleaning services, but there was also an underwater movie planned, about the salvage of Russian museum treasures stolen by the Germans during World War II — treasures that sat in sunken warships off the Crimean coast in the Black Sea. These recent iron ships were of little interest to me, but the Soviets had also spoken of "a sailing-ship, well-preserved, from ancient times with cargo, sunk in a depth of 100 meters, 40 km offshore." An ancient wooden ship in good condition, beyond the reach of divers, would be a prize indeed. I had long believed that if an ancient ship were to be found complete, it would be in the Black Sea because of the unique chemistry of the deep waters there: below 130 meters there is no oxygen and therefore none of the boring animals that consume wood in most seas. Wood there may survive forever. A hundred meters was not quite deep enough, but who knows? I decided to pursue the matter.

A month later, more information came from Valery Zdorovenin, general manager of the Soviet half of the joint venture. The ship, he reported, had been accidentally discovered in 1980 during a submarine search for a downed helicopter. The sub's pilot described the sea bottom in the area as flat and sandy with water visibility of 10 to 15 meters. He noted that "the ship's hull is partially buried in sand and its two masts have fallen; through holes in the deck its cargo of amphorae can be seen."

Imagine! An ancient ship with much of its wooden hull remaining, plus masts and cargo, untouched by any previous archaeologist. No such ship has yet been discovered; usually only the bottom planks and ribs are found beneath the mud that has buried them and protected them from borers.

In the following weeks, the story steadily improved. The length of the ship was estimated at 50 meters; parts of the wooden hull were said to rise two meters above the bottom. Pieces of wood were spread around nearby, as were amphorae, the distinctively shaped two-handled, narrow-necked jars that the ancient Greeks and Romans used to store and transport wine or oil. In 1980 and 1981, a Soviet admiral named Lev Mitin had organized two searches with small submarines, but had failed to find the wreck. Admiral Mitin, now retired, had been the chief hydrographer of the Black Sea fleet and an expert navigator. He was sure of the wreck's position "within tens of meters."

Valery consulted with Dr. Mischa Agbunov, one of the few undersea archaeologists in Russia and an expert on the history of the Black Sea. He too believed the story but had no explanation why two previous searches had failed to find the wreck if the position was so well known.

By this time I was looking for equipment, personnel, and financing for an expedition to locate the wreck (sponsors ultimately included the Kelton Foundation, the Natural History Museum of Los Angeles County, the Scripps Institution of Oceanography, the Explorers Club, Dr. and Mrs. Roger Revelle, Rheba Lutz, Claire Tavares, and three of the expedition members). But before going further, I wanted the position of the wreck. This started an argument between Admiral Mitin and archaeologist Agbunov over the terms of transfer of that piece of information. Finally I invited both of them to join us on the expedition.

Then an allegedly original copy of the report on finding "the sunken ship in Kalamitsky Bay" arrived, and shortly thereafter, a letter from the commander of the small sub that had originally sighted the sunken ship. In a letter to the Soviet Academy of Sciences dated April 16, 1991, Captain Anatoly Pavlov said that after ten years his recollections were a little vague, but he repeated much of the information we already had. He concluded, "The ship was found with the sub's sonar and then

Ships like these small Roman cargo carriers (fancifully portrayed in carved relief on a sarcophagus, with greatly oversized crewmen) were common in ancient times. They had rounded hulls, a single mast with a square sail, a bowsprit with a smaller sail to keep the ship aligned with the wind, and double steering oars at the stern with long tiller handles for the helmsman. The construction of such ships is of some interest to marine archaeologists, but the cargo and artifacts that might survive can give a much better picture of the time and civilization the ship served. The author was searching for such artifacts at the bottom of the Black Sea.

observed directly. I am prepared to personally take part in a search for the sunken ship."

Soyuz Marine offered to provide me with a suitable ship for two weeks of searching, transport for our party of explorers from Moscow to and from the ship, translation services, and a complete set of permissions from the Navy, the KGB's "shore watch," and miscellaneous other government agencies.

This sounded like a good deal, but I hedged the bet with an advance reconnaissance trip in mid-April to see if all was as claimed. By then enough commitments were in hand to assure that the expedition could be financed if operations in the then-U.S.S.R. seemed feasible. With me were Don Keach, Valery, and a Russian translator.

Russia had at that time a lot of problems that have since gotten much worse. Little maintenance appeared to have been done on anything for years, and the food supply was marginal; there was very little to buy in the stores either with rubles or dollars. Although our party would be mostly insulated from the system, these factors would have some effect on our work.

After 24 hours by train and car from Moscow, our reconnaissance party arrived at Yalta, a lovely city pressed by pine-covered mountains against the sea. We had to go to Yalta to inspect the ship that we would use because its home port, Sevastopol, was closed to outsiders.

The ship *Trepang* was a gem, exactly right for searching. A steel shrimp trawler built in Poland in 1986 and converted into a research ship in 1990, it had a crew of 14 and berths for eight scientists. There was plenty of working space on the after deck, a large "A" frame, hydraulic winches, and good instrumentation, including a radio telephone with which we could contact the U. S. by satellite. Best of all, its captain, Yuri Petrovitch, was a fellow who knew how to sidestep the unexpected regulations that sprout on all sides. A couple of the officers spoke some English.

Admiral Mitin visited the ship when we did, apparently to reassure me that he was still willing to direct the expedition — a suggestion that was discreetly ignored. The admiral was red-faced and portly, with a personality that ranged from friendly to overbearing. As a gesture of goodwill he presented me with an artist's conception of how the wreck would look when we found it. It was drawn from the account in the report and showed a large wreck with high sides, two crossed masts, and many amphorae. He signed it and insisted that the rest of us do likewise to certify that he had told us in advance exactly what we would find.

Once again we asked the position of the wreck. He repeated one of his original demands: our group would have to guarantee to raise the wreck and put it in a Soviet museum. I noted that there was no museum large enough to hold a 50-meter-long ship, and that no one knew the structural strength of its long-immersed wood. (I also mentioned that Americans are not all that rich.) We proposed that any decision about how to proceed be made after we found and examined the ship.

Finally we agreed on a signed "protocol," which promised that the admiral would get copies of any significant data that our expedition produced. When he finally gave me the wreck's position, it was with the stipulation that I tell no other Russians. I agreed. As we shook hands and bear-hugged, I hinted that we should toast our agreement. His response was instant; he went up the ladder two steps at a time to find the vodka, and we got a party going that resulted in at least one hangover.

Back in the U.S., our inner circle met to look at TV tapes of the ship and make a final decision. It was "Go!" but by now there were only nine days before our plane left. Four of us would be going, but our equipment was not yet ready, and none of us had visas. We knew that Soviet travel rules were rigid; a detailed plan had to be submitted in advance, and once it was accepted you must be in the city named on the days you had selected. No changes! Thus our time at sea would be determined by the visa and the difficulties of changing flight schedules. Time was too short to permit a single error; if we missed any one of dozens of deadlines, the whole project would collapse, because success depended on every piece of equipment and every person being there.

Visas caused the most heartburn. Although we promptly got the visa requests off to the consulate in San Francisco, we did not know that Soviet May Day celebrations lasted a week in the U.S.S.R. (and two days in San Francisco). We fumed and sweated, but two days before the plane left, the visas arrived.

We brought three main items of equipment: a side-scan sonar, used for searching the bottom, a Global Positioning System for satellite navigation, and an R.O.V. (Remotely Operated Vehicle), which is something like a small submarine on a leash carrying a television camera that records on deck. The sonar, a Klein 595, was operated by a very bright, hard-working fellow named Mike Sutter, who also served as the operator of the R.O.V.

In addition, we brought a Honda generator, an automatic camera in a case that would survive at 100 meters, strobe lights, a VCR, a T.V. monitor, and other equipment. This pile of high-tech apparatus, which filled five large wooden crates and three small ones, was delivered to Finnair

freight the afternoon before our flight. There was no time for proper customs papers, which take a couple of weeks to prepare, so this mass of equipment weighing some 400 kg. and worth over $80,000 would have to go as my personal baggage. That cost $1,800, but it insured that these essential items would not get lost in Moscow's air freight terminal.

The last hours before departure were much like an implosion. We all dashed about on last-minute errands; somehow all the pieces and people came together at ever-increasing velocity until, just before the moment of takeoff when nothing more could be done, calm settled upon us. Richard Kelton, our navigator, carrying our new Magellan Navigator that would fix our position at sea within 20 meters; Mike Sutter, with about 60 pounds of tools, ready to fix anything; and I, Willard Bascom, the exhausted organizer, were ready to sleep all the way to Helsinki. At Helsinki airport we met the fourth member of our expedition, Marvyn Carton, a former navigator for American Airlines.

At the passenger terminal in Moscow airport I collected my monumental baggage on luggage carts, and, with a straight face, waited in a long line of people who were merely equipped with suitcases. The Russian customs officers were duly astonished and requested that we pile the boxes next to their desk until a decision could be made by higher authority on the admission of our gear. And so we did, while Valery translated, coaxed, and waved papers at nameless bureaucrats in various locations around the city. Mike sat on the boxes for four hours until Valery returned triumphant.

Then our special freight was moved to the train we would board at 7:30 the next morning by Mischa Agbunov, our archaeologist. In the course of so doing Mischa rediscovered the infamous underground market that operates in the railroad yard at night. Armed only with a few bottles of vodka, he managed to get our boxes loaded by midnight; then he guarded them until morning while the rest of us slept at the Academiska Hotel. (We had bought an entire compartment of the train to be used only by our large baggage but the conductress insisted that we pay for the linens that went with that compartment.)

The train ride south in the Russian spring to the green fields, budding orchards, and small towns of the Ukraine was pleasant in spite of its length. Early Sunday morning we were met at the Yevpatoriya station by the *Trepang*'s Captain Yuri, who demonstrated his personal enthusiasm by helping carry the heavy boxes to the bus.

Yevpatoriya is a pretty place with tree-shaded streets and little traffic. It is used mainly as a summer vacation place for kids, who were not yet out of school, so we found it quiet and sparsely inhabited. In an hour we and our boxes were safely aboard the ship — a substantial achievement.

D.J. Choi

The Black Sea is like a small ocean, very deep in the middle and bordered by a flat continental shelf built by sediments from the surrounding lands. Several large Russian rivers flow across it and out through the Bosporus so that the salinity is only half of that in the ocean. Below this clear surface layer, there is no dissolved oxygen in the water and consequently no marine borers or other sea life. In such water, wooden ships may survive indefinitely.

The ship had ample electric power, but because it was 50 cycles and likely to be somewhat variable in voltage, we had brought our own 60-cycle generator that ran on gasoline. Then we learned that gasoline was forbidden on shipboard in the U.S.S.R.; moreover, one had to have coupons to buy it, and no fuel was available early on a Sunday morning. However, in a couple of hours the crew had rounded up an empty drum and filled it by siphoning a little from each of a procession of trucks. We were careful not to ask questions.

While waiting for the gasoline, we four Americans, accompanied by Valery to interpret, visited two museums to see what local history had been preserved. This part of the ancient world was humming by 500 B.C.; Scythia (now the Ukraine, which includes the Crimea) was a rich and powerful country, and Greek city states had outposts along its coast. Thus there was considerable ship traffic, and presumably ship losses. The local museums displayed many varieties of amphorae and odd wooden artifacts recovered from the sea. This was a favorable sign; at least we would be looking in the right part of the world and on the main ship

route between ancient Olbia and Chersonesus (now Odessa and Sevastopol).

In late afternoon we met with the captain and officers to explain our plans (where to start, how slowly we would need to tow, special care on turns, how to prepare marker buoys for quick launching), and I described the navigation plotting method I had devised before we left home. Basically it was a blank chart with an arbitrary grid on it in which one kilometer of bottom was represented by 10 centimeters on the chart. Two kilometers are about one nautical mile, which meant we could easily plot the global positioning fixes, which are in hundredths of minutes, with a simple scale, and directly measure distances in meters. Admiral Mitin objected that it was not the way he would do it, and the other Russians seemed skeptical. But since we were paying the bills, we prevailed. I was confident that by tomorrow night everyone would see how satisfactorily it worked (that prediction proved accurate).

*Marks on the ocean bottom seem to remain for a long time, perhaps twenty years or more, until a great storm erases them.*

The final instruction to the captain was, "Have the ship on station ready to go at 5:00 tomorrow morning." Richard Kelton got our navigation system running and Mike Sutter installed the sonar on the bridge deck where the operator had a good view of the after deck and the cable trailing out behind. We were ready to go!

Soon we became aware that there was a young woman aboard taking pictures with a TV camera, and we asked how she came to be there. It seems that the day before, a special order had been issued by the Soviet Navy, indicating that a new aircraft carrier would be on trials in the region of our operations, and we would be required to stop working at three in the afternoon. Our captain responded by contacting a retired admiral friend who retained some clout. This gentleman's view was that the ban might be lifted if his daughter, newly employed by a Sevastopol TV station, could accompany us for a few days. So she did, and the ban was waived. At such times the Communist system seemed to work about like ours.

The plan was to search along north-south lines that were 150 meters apart; north for two nautical miles (four kilometers) then a turn and south on the next line, and so forth. This meant the sonar would see a 300-meter-wide swath at all times and have a 100 percent overlap. Such an overlap was necessary because it is difficult to recognize targets that are directly below the ship or at the extremities of the sonar swath. A side-scan sonar sees its targets best when they are at a low angle.

Our search began about 1.5 kilometers east of the position given by the admiral; from there a succession of survey lines would sweep across the area moving westward. By 10:30 p.m. we had finished nine lines and had passed over the wreck's alleged position without finding anything of interest. No matter; we were happy that the system was working well. Exhausted by jet lag and a very long day, we flopped into our bunks.

My original intention was that our party would work the usual ship watches of four hours on and eight hours off, but we did not have the manpower. Since there were only four of us, we all worked 16-hour days.

The weather was ideal when we began, the breeze light, the sea flat, and the sun shining through moderate clouds. The temperature was cool in the morning and comfortable in the afternoon. Small colorful land birds that were migrating would come aboard to rest and were so tame that we could catch them in our hands.

Now we got into the routine of the ship: breakfast, consisting of bread and tea with an egg or a bit of cheese, was at 8:00, long after we had started to work. The bread was brown and tasteless; Carton joked that it had probably been designed for use as heat shields on missiles. Then Gina, our happy, fast-moving young cook, took to baking his own bread, and things improved considerably. Lunch and dinner were indistinguishable. There was a bowl of soup (the same soup expanded each day in a great pot on the stove), a bowl of cereal grain with some pieces of meat atop it, bread, radishes, and cucumbers; and some cold drinks we never did identify and rarely drank. This was considered to be very good fare by the crew, and we mustered as much enthusiasm as possible.

The second day of searching began clear and calm with all hands on deck by 5:30. We sensed an immediate comradeship with the crew; there were lots of smiles and handshaking. By 6:24 we had picked up our first target, an array of dark slashes and white shadows on the sonar scroll. But we continued on, made a turn, and at 7:32 the sonar detected that same spread of material again from the next search lane. Some of the reflecting objects were spread out from northwest to southeast as though a trawl net had run across one edge of the target and scattered pieces in a straight line. Perhaps that was our wreck! However, it was a smaller target than what we were expecting, so we continued on.

Most of the bottom seen on the sonogram was unscarred, but periodically its constant

gray had a lighter gray fan-shaped pattern where some ship had anchored and swung on its anchor line. We were surprised to learn that such marks seem to remain for a long time, perhaps twenty years or so, until a great storm erases them. (We had been led to believe that the sedimentation rate was great and the currents strong, and that the sonar would detect marks only a few centimeters deep.) One of these fans may have been made by the small sub's mother ship in 1980. I was reminded of a line from Kipling: "The great grey level plains of ooze where the shell-blurred cables creep."

There were numerous pairs of white tracks, straight and parallel, about 50 meters apart, running northwest to southeast across our north-south survey lines. These were almost certainly the marks made by trawl "doors" used to keep bottom nets open, dragging in the soft bottom. Some of these tracks consisted of a precise dashed-line pattern with dark and light alternations about a meter long. The most logical explanation we could think of for these was that some fisherman had used large gear-like wheels on his trawl doors that left this special impression. We rejected suggestions that these marks were made by submarine propellers, dinosaurs, mine-sweeping paravanes, or trawl doors chattering.

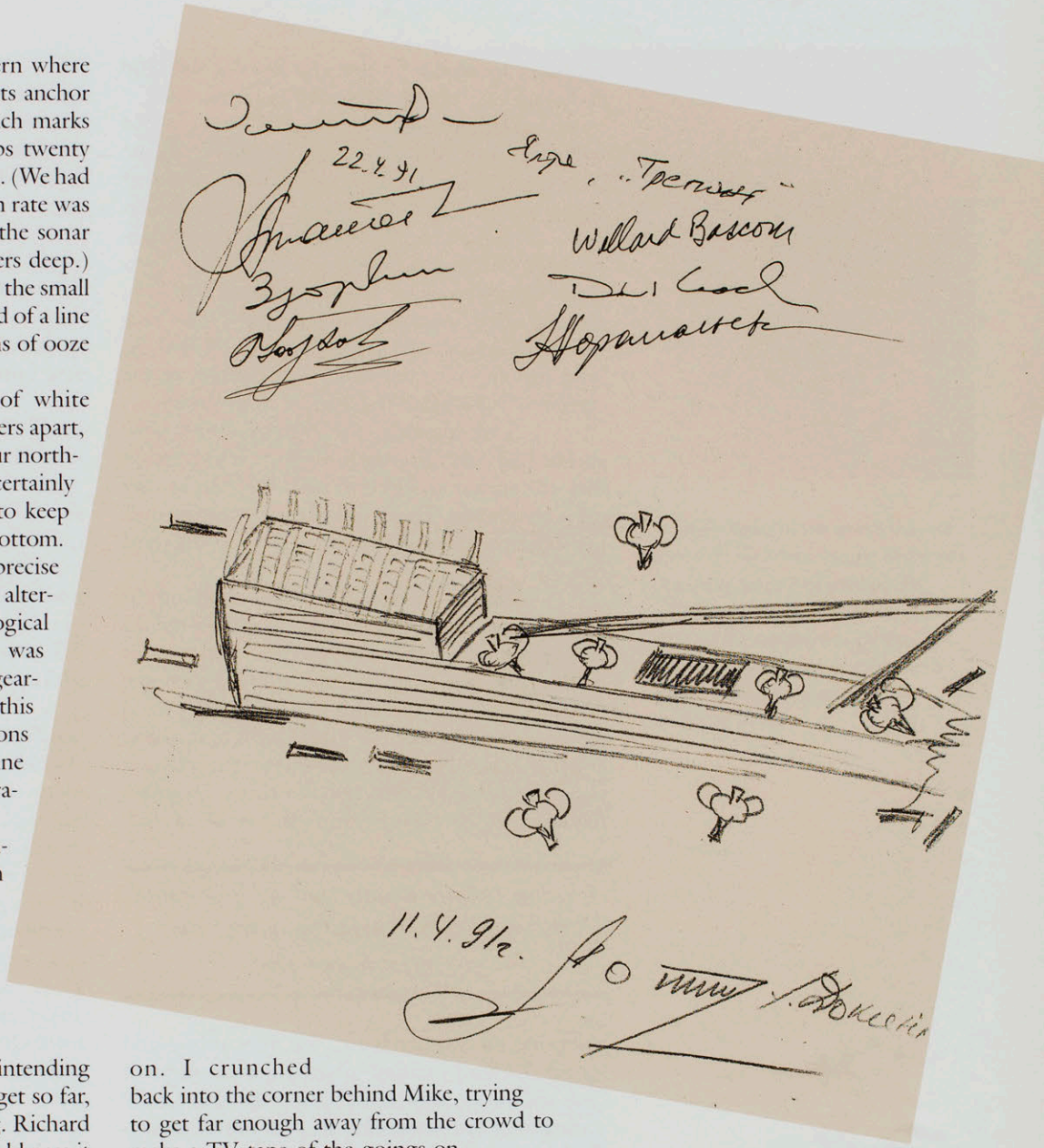
The plan was to continue searching until we had covered a mile in each direction from the admiral's position, at which time we would go back and re-examine the best of the contacts, looking at these from a different direction and at a lower altitude. By 7:30 in the evening, we had completed the last line to the west and headed the ship eastward, intending to come close to our most promising target so far, which had been found early that morning. Richard Kelton was asked to lay a course that would pass it 20 meters to its north. Only half the length of the *Trepang*!

At 8:25 p.m. on May 14th, the sonar produced a very exciting image of what was clearly a ship lying in the midst of a crater dug by the impact of its collision with the bottom. The fact that the wreckage was only 15 meters long did not dampen our enthusiasm. I cried "Eureka!" and hugged Richard, at the same time asking him to set another course that would pass the target on the south side.

By now all hands were alerted to the find, and Mike's small sonar space at the rear of the bridge was jammed. Inside were the ship's officers, Marv Carton, Admiral Mitin, Mischa, Valery, and Richard. Outside, with their faces pressed to the windows, were about eight crew members with happy, excited faces, eager to see what was going on. I crunched back into the corner behind Mike, trying to get far enough away from the crowd to make a TV tape of the goings-on.

This time the sonar image was even better, and as it emerged, the multitude cheered. We imagined we could see the masts down, dark ribs with white shadows, and the high poop deck, just as described. The captain was instructed to set a three-point mooring to hold the *Trepang* above the wreck, and we went to bed in a state of euphoria. Next morning Richard and I each telephoned home via the ship's satellite link to tell the good news and got our money's worth of excited confusion.

On one of the passes, our ship ran directly above the wreck and at the navigator's shout we heaved a buoy to precisely mark the spot. It consisted of an iron clump, 100 meters of light nylon line, and an old life jacket. Because our R.O.V. cable only allowed us to search about 40 meters, it was




The drawing by Admiral Mitin of the wreck seen in 1980, from the submariner's description. It shows a lot of wood remaining at the stern, two masts, and amphorae scattered around. Those present were asked to sign the drawing, verifying that the Admiral knew in advance exactly what we would find. Unfortunately, the actual wreck was nothing like this.

necessary to anchor so that the stern of our ship ended up only about 20 meters from the buoy.

Although the captain had been warned well in advance that a three-point mooring would be needed, he had been unable to obtain sufficient anchoring gear. In a three-point moor, the ship is held between three anchors spread in different directions, so it cannot be moved by winds and currents. By adjusting the length of the anchor lines, the ship can be positioned exactly above the wreck below. Ordinarily the bow anchor is set first, to hold the ship into the wind or the waves or the current — whichever is the most troublesome.

Unfortunately, the *Trepang*'s main bow anchor had only 150 meters of chain, which meant that our anchor would only hold the ship in very calm conditions. There was no way to maneuver the ship to set a second anchor, much less the third one.

May is statistically the calmest month to work in this part of the Black Sea; however, the sea conditions are also most variable during this month, and for two days the ship "chased the wind." Each time the anchor was set, the wind would shift or the current would seem to increase, and the anchor would have to be hauled in and reset to fit the new wind direction. Of course the main requirement was that the ship's stern end up close alongside the marker buoy. We went round and round. Richard carefully plotted the positions of each anchor set and each position the ship finally settled into, but in the end his plot was an indecipherable maze.

*I began to have doubts that we had found the right ship. Carton suggested that "Crimea doesn't pay."*

The crew's performance seemed a bit like the Keystone Cops as they worked around the clock for those two days, resetting the anchors. When we arose at 5:30 on the third day to start work on the wreck, Valery told us we might as well go back to sleep. While working hard in the middle of the night to get the ship properly positioned, they had tangled two mooring lines and had to cut one cable, loosing a concrete mooring block. We were adrift.

Later in the day they tried again, still without much success. Richard finally left the bridge, laughing, "It's too painful to watch." But eventually the wind moderated, and the ship settled into position next to the buoy. We learned later that the ship had not been at sea for over a year for lack of operating funds, and the crew were all out of practice.

Overside went the R.O.V., with our underwater TV camera, guided by Mike Sutter from a tiny control room on the ship's stern. On the way to the bottom, we could see jellyfish and transparent, golf ball-sized creatures that trailed diaphanous streamers from each side.

Once again we had to search for the wreck. Now the method was to guide the R.O.V. to the extremity of its reach and, if nothing of interest was encountered, to steer it back along its own cable to the point of beginning. Then it would be sent outward in another direction.

We quickly learned that the bottom was made of very fine brown clay particles and that its normally smooth surface was easily marked by our almost-buoyant cable and ploughed effortlessly by the R.O.V.'s frame. These contacts resulted in a haze of smoke-like dust that temporarily reduced the visibility. This extreme softness was the reason why a large impact crater had formed around the old ship when it crash-landed many years before. The depth of the water prevented the Black Sea's short period waves from disturbing the bottom.

Just before midnight on May 17th, the watchers peering over Mike's shoulder in the tiny control room began seeing miscellaneous small pieces of wood on the TV monitor. Then a squared-off stick of wood slanting out of the bottom snagged the R.O.V.'s red umbilical cable; that gave us a few bad minutes. The top of a clay jug (no handles were visible as on an amphora) rose a few centimeters above the bottom and came into view, and beyond it appeared a line of stake-like objects. These were the ship's ribs; they were small, perhaps 10 centimeters square at the base and projecting 30 to 40 centimeters from the bottom, tapering up to a gnawed-off-looking terminus. All the wood pieces had a fuzzy exterior of sea growth.

About this time the vertical thruster on the R.O.V. failed, which meant that it could not hover and instead dragged bottom as it moved about. The result was a storm of white particles in front of the TV's lens that temporarily blotted out all else. There was nothing to do but wait for these to settle down so we could see.

The R.O.V. made another darting move, and we waited again. Inspection of the wreck was slow but fascinating as we tried to peer into the dark beyond the reach of the light and behind the froth thrown up by any motion.

The particles on the wreck were quite different from those outside it. They may have been fragments of decayed wood or other biological materials from animals attracted to it. Often many of the particles in these irritating clouds would appear to be toroids (doughnut shaped). I suspected at the time that this was some phenomenon related to the

lights and the camera lens, but my daughter Anitra later came up with the theory that the bottom of the Black Sea is paved with Cheerios. That is a very imaginative idea, backed by the evidence of many pictures; if it eventually checks out, it will be a scientific breakthrough indeed.

We retrieved the R.O.V. and repaired it in a dense fog that rolled across the afterdeck; by the time the R.O.V. was repaired, it was 2 a.m., and we were exhausted.

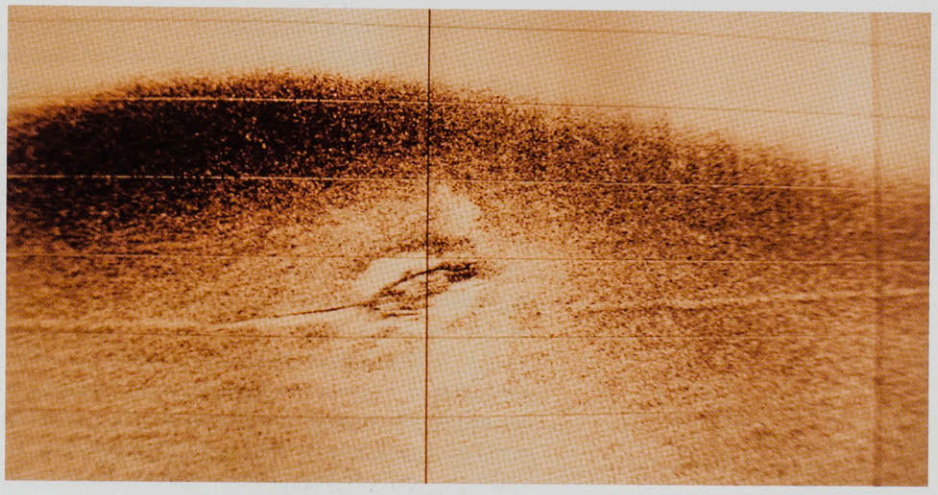
In a half-sleep the next morning, my mind was on the discovery we were about to make. None of us doubted that the rest of an ancient ship would show up on our monitor this day. We would be the first to see the high wooden stern section and retrieve a virgin amphora. My thoughts were on Howard Carter's words when he first peered through the slot into King Tut's tomb. Someone asked what he saw, and he replied, "Wonderful things." Drowsily I tried to think of something that would be equally appropriate.

While the ship was almost directly above the wreck the next morning, Richard made a particular effort to fix the wreck's position exactly. What he came up with was about one-third of a nautical mile from the position given by Admiral Mitin.

We were eager to bring up one of the amphorae that had been described by the original finders, so Mike attached a device known as the Happy Hooker to the front of the R.O.V. This provides a clever means of passing a line through an opening such as the handle of an amphora. From then on the Happy Hooker occupied much of the lower left hand corner of our TV screen and obstructed some of the bottom ahead. However, this annoyance was more than offset by the advantage of having an object of known size in the picture.

On the next trip to the bottom we came across some wooden poles or spars, and it was easy to understand how someone could be fooled into thinking they were much bigger than they really were. But, knowing that the end of the Happy Hooker was exactly 11 centimeters high (4.5 inches), we could say with certainty that the spars were no more than 14 centimeters at the large end nor more than about three meters long — much too small to be a mast. A vertical post, somewhat larger, possibly the stump of a mast for a boat only 12 meters long, stuck up about 30 centimeters.

Looking toward the hulk from the outside, we could make out the siding of this vessel. Our Happy Hooker scale showed that it rose no more than 20 centimeters above the clay bottom. There were other objects: wood with holes for some unknown purpose (one of these now serving as a fish's home), a thin wooden arch, the tops of two more jugs, but no definitely recognizable amphorae. I began to have doubts that we had the right ship. Marv Carton suggested that "Crimea doesn't pay."



A sonar record of the wreck that we found shows how a picture of the sea bottom is created by printing the reflections of a series of pings of sound. One can see a small ship outlined by the stubs of ribs amid a crater in the mud created by the impact of its fall.

The wind had been rising steadily, bringing concern that the ship would drag its anchor across the wreck and ruin the site. It would be the worst of all worlds to find and destroy an old ship on the same day. So we picked up the anchors and waited for the weather to moderate. The ship's barometer was falling and the weather fax system produced a forecast that showed us at the apex of three converging occluded fronts. What the heck did that mean?

While waiting, we met in the wardroom, our group of four plus Admiral Mitin, Dr. Mischa Agbunov, and Valery Zdorovenin of Soyuz Marine, who interpreted. We began by noting that in five important respects, the wreck we had found did not agree with the description of the one we were looking for. The bottom was not sand, the ship was much smaller than the 50-meter estimate, there were not two masts, there was not much exposed wood, and there were no amphorae.

The question before us was: is the position wrong, or is the description wrong? Admiral Mitin insisted that his position was correct and that we had found the right ship, but when we reminded him of the picture he had given to us of all the wood and amphorae, he shrugged, "what can I say," and turned his back. Mischa and the admiral both thought we should search more on the site we had; we did not disagree, but worsened weather would not permit that.

Mischa suggested that maybe a trawl net had been dragged across the wreck since its sighting 11 years ago, picking up the amphorae and scattering the stern and masts. That did not seem likely; the only pair of trawl scars visible on the sonar were outside the hulk, and we could see no

clear signs of trawl damage.

It seemed most likely that we had found a different wreck, and we decided to search some more with the sonar. After a discussion with the captain of the problems in the 1980 radio navigation system, our best chance seemed to be to extend our survey lines to the east. But about this time we got an updated weather fax, which showed a very deep low-pressure area with high winds moving eastward from Europe. It was just about to pass across the Black Sea.

The skipper decided that the ship had better run into Yevpatoriya for safety and take on water while we waited. Even this simple maneuver entailed bureaucratic delay; the *Trepang* was required to wait offshore for several hours in the early morning while the harbor authorities "considered our request to enter the port."

Carton, Kelton, Sutter, and I were now sailors with half a day of shore leave, and we made the most of it. Yevpatoriya is basically a pretty city, with tree-lined streets and nice old buildings. Two old churches being rebuilt attracted us. It was Sunday and we found them largely filled with old women, standing amid walls decorated with golden icons and tile work. The city's bus and trolley system seemed to work well, but the few stores were shabby and had meager stocks. We managed to find the best restaurant in town, where a lunch for five with wine and three courses cost three dollars worth of rubles. As special presents for the ship, we bought some coffee (how can a work ship operate without it?) and currant jam for the morning bread.

That night we were back at sea, and by 3:30 the next morning the sonar was tat-tat-tatting away as we ran north-south lines on the eastern side of our original grid. We had searched 24 square kilometers, or six square nautical miles. Most of the targets found were in the area around the shipwreck and helicopter crash site. So we were forced to the conclusion that probably we had found the right ship but that the description of it was way off. As the wind was still strong and the waves were about two meters high, we could not return to the wreck and anchor over it, much as we wanted to see it again.

By now we had about eight hours of TV tape and a pretty good understanding of the ship's size, shape, precise position, and condition. What we did not have that I especially wanted were samples of the wood for carbon 14 dating and strength tests, nor samples of the clay and the white material around the wreck. And of course, we had not collected one of the mostly buried clay pots.

The observers on the submarine seem to have greatly misjudged the size of their find and thus created another Russian fairy tale. Poor translation and the over-enthusiasm of the admiral seem to have added to it, but considering the evidence they had, it was a good bet. We might have had an untouched ancient ship, and that would have been a treasure indeed. What we found appears to have been between 50 and 200 years old, judging by the exposed wood and the condition of the crater. We made no plans to return to this ship, although my view that there are nearly complete ancient wrecks below 130 meters in the Black Sea is unchanged.

In our two weeks together, a lot of mutual admiration had developed between us and the Russians. We liked their willing attitude and sincerely enjoyed working with them; they liked our style but remained puzzled as to why "American millionaires" would want to go to sea on a work ship. These Russians did not like to get up early in the morning, and it was a mystery to them that we stayed on the bridge most of the night as well. They especially liked Mike Sutter, who worked long and hard, smiling all the while. They were genuinely sorry to see us go, and Captain Yuri broke my glasses with his final bear-hug. The crew was especially pleased with the polaroid photos Richard game them of all of us together.

The night before we were to take the train back to Moscow, the ship's crew threw a party for us in the wardroom. There were fancy hors d'oeuvres, steak, potatoes, ice cream, cake, and coffee — and, of course, vodka for toasts. A lot of short speeches ended with "wodka" being lifted, and a lot of warm feelings were expressed. We happily toasted the first American-directed joint American-Russian expedition to the Black Sea. When they said my name would be remembered in history for this great achievement, I was reminded of the "shout of triumph in a soundproof room," a remark attributed to Peter Ustinov.

For us the expedition was a success in that we found and examined the ship we sought. The venture was good practice, and now we know what we can do. There are other wrecks out there in the Black Sea waiting for us to come and find them. We'll be back.

*Willard Bascom has been involved in the ocean sciences since 1945, beginning with research on waves at the University of California at Berkeley and the Scripps Institution of Oceanography. He organized and directed the first deep ocean drilling for the National Academy of Sciences and the successful search for undersea diamonds off Namibia for DeBeers. His book* Waves and Beaches *is widely used as a beginning text in oceanography, and his love of archaeology has led him to years of study of shipping in the ancient world. In 1992 he was awarded an honorary doctoral degree in natural sciences by the University of Genoa.*

# The Paintings of Robert Bateman

CANADIAN ARTIST AND NATURALIST Robert Bateman has attracted an enormous international following for his exquisite paintings of animals and natural settings. His work is included in the permanent collections of HRH The Prince Charles, HRH The Prince Philip, the late Princess Grace of Monaco, Prince Bernhard of the Netherlands, and several prominent art museums. Books of his work have been immensely popular, and he has been abundantly honored, having received, among other tributes, Canada's highest civilian award and eight honorary doctorates in arts and sciences.

Over a lifetime of empathy for animals and of studying and constantly sketching their movements, moods, environments, and behaviors, Bateman has produced a body of work without equal. A former teacher with an honors degree in geography, he uses his field sketches and photographs, as well as museum specimens, for his research. He travels extensively to sample the diversity and spectacles of the natural world.

Out of this careful preparation arises not only the accuracy of detail that comes from scientific knowledge, but also the mysterious alchemy of his art; for although detail and realism are the qualities for which Bateman's works are celebrated, these attributes do not emerge from the mere labor of painting detail. Rather, they come from Bateman's understanding of the energy contained in his subject, and from his technique of laying down light and shadow, and then building on top of it, little by little, the life of a bird, a cougar, an elk. The life of his subjects, therefore, materializes from the underpinning he has created for them rather than being projected outward from a human's perspective.

The power of this process pulls people forcefully into the milieux he creates — full-blown mini-universes with every fragment of life faithfully locked into the moments of peace, calm, tragedy, or confrontation that he portrays.

Since the early 1960s, Bateman has been active in conservation and naturalist organizations, including the Ambassadors Club of the Convention on International Trade in Endangered Species of Wild Flora and Fauna. With a fine appreciation not only for the beauty of nature but for its fragility, he has used his artwork in many preservation-oriented fund-raising efforts.

"One of my favorite sunsets," he has said, "is one with a spider web and a tiny spider living in his little world . . . Our little world is very tiny and

*Above the River — Trumpeter Swans*, 24 by 42 inches, oil. "I chose the trumpeter swans as the counterpoint to the river because I enjoy the tension between their dusky pale blue and the bright creamy river. In addition, I was expressing my delight in the recovery of a population of this bird, which was once endangered." Copyright 1981, Robert Bateman.

Courtesy of the artist and Mill Pond Press, Inc., Venice, FL 34292.

*Dozing Lynx*, 36 by 48 inches, acrylic on masonite. "The lynx in an animal of mystery. Although they are relatively common within their range, they are very seldom seen in the wild. They are mostly nocturnal hunters, and they can move quite silently. My painting shows the lynx in a late evening's tranquil moment at the entrance to a cave. It is at peace — lightly dozing prior to its night hunt." Copyright 1987, Robert Bateman.

just as fragile as a spider web. . . . Every little strand is important. And in the thin life membrane of this planet, there are trillions of strands. You have to treat their preservation as a high priority."

In the paintings on the following pages, which are accompanied by texts written by the artist, and in the approximately 45 works on display in the Director's Gallery of the Natural History Museum through March 28, 1993, Robert Bateman's unique vision of the natural world is abundantly reflected.

Courtesy of the artist and Mill Pond Press, Inc., Venice, FL 34292.

*Everglades*, 70 by 89 inches, acrylic on canvas. "The warm climate and abundance of sun and moisture make the Everglades one of the richest natural areas of the world. It teems with a multitude of life forms, from giant alligators through deer to small amphibians and fish. The most exciting and obvious of all, however, is the bird life; there are many species of herons, egrets, and exotic spoonbills and waterfowl. In this painting, which depicts an early morning, I have tried to capture the lush serenity and the sense of harmonious abundance of the Everglades." Copyright 1986, Robert Bateman.

Courtesy of the artist and Mill Pond Press, Inc., Venice, FL 34292.

Courtesy of the artist and Mill Pond Press, Inc., Venice, FL 34292.

*Wildlife Images*, 48 by 42 inches, acrylic on masonite. "In this painting, I have tried through my choice of subjects to depict the harm that man, by design or through carelessness, does to the environment." Copyright 1990, Robert Bateman.

Courtesy of the artist and Mill Pond Press, Inc., Venice, FL 34292.

*Mossy Branches — Spotted Owl*, 16 by 20 inches, acrylic on masonite. "I particularly like the mysterious and nocturnal owl. It is always a surprise to see an owl as it stays within thick cover. Owls . . . inhabit our old-growth forests; they are the denizens of the remnants of our sacred places. I see the spotted owl as a kind of hapless symbol of what we have to do to preserve a huge and very important ecosystem — the North American temperate rain forests." Copyright 1989, Robert Bateman.

*Midnight Black Wolf*, 36 by 48 inches, acrylic on masonite. "Wolves and man have very much in common: both species are gregarious, have a hierarchy of status, teach their young, and work in cooperation. The species' rivalry, however, has fostered a tradition of mutual distrust. An encounter makes the hair stand up on the back of the necks of both man and wolf.

I wanted to show the ominous presence of a mature, lone wolf. I wanted to create a mood of seriousness and respect — not threat." Copyright 1989, Robert Bateman.

Courtesy of the artist and Mill Pond Press, Inc., Venice, FL 34292.

*The Air, the Forest and the Watch*, 30 by 46 inches, acrylic on masonite. "The air is the eagles' domain. I have usually observed bald eagles in a landscape of somber power. In winter it is possible to see a dozen or more of these great birds along the shores of fast moving mountain waterways." Copyright 1989, Robert Bateman.

Courtesy of the artist and Mill Pond Press, Inc., Venice, FL 34292.

*Lioness and Wildebeest*, 40 by 45 inches, acrylic on masonite. "This painting shows the tougher side of nature, but it is nonetheless real and important. I deliberately painted the lioness as subdued and almost transparent, partly as a reaction to the normal dramatic depiction and partly because lions do blend with the landscape." Copyright 1990, Robert Bateman.

Courtesy of the artist and Mill Pond Press, Inc., Venice, FL 34292.

The Natural History Museum's shops will feature several books of Robert Bateman's art, as well as an assortment of posters, calendars, and videotapes, during the museum's exhibition *Natural Visions: The Art of Robert Bateman*. The books include *Natural Visions: The Art of Robert Bateman; The World of Robert Bateman; Robert Bateman: An Artist in Nature;* and *Robert Bateman: A Retrospective of Limited Editions, 1978-1991.*

# Exposition

**Q: At the last museum Open House, I had a discussion with one of your curators about an interesting fossil from the Burgess Shale in British Columbia, *Wiwaxia corrugata*. Originally this fossil was described as a Cambrian polychaete worm. However, Stephen Gould of Harvard, in his book *Wonderful Life*, said *Wiwaxia* was not a worm, that it was either a primitive mollusk or belonged to some new phylum. What is the story here, who is correct?**

**A:** *Wiwaxia* is certainly one of the more interesting creatures from the Burgess Shale, a formation of unusual preservation some 550 million years in age. This creature's peculiar form has given rise to a variety of opinions about its affinities. The problem has been how to interpret the scales that covered the *Wiwaxia* body.

In a recent study by one of Professor Gould's colleagues at Harvard, Dr. Nicholas Butterfield solved the problem in a most interesting way. Burgess Shale fossils preserve residues of the original organic material. Butterfield took some *Wiwaxia*, treated them with acid to remove the rock from around the fossils, and then examined the scales with light and scanning electron microscopes.

Polychaete worms have many spines of distinctive form on their bodies. Indeed,their name alludes to this: *poly* means many, and *chaete* means spines. Butterfield discovered that the Wiwaxia scales were actually flattened spines identical to those seen on certain kinds of living polychaete worms. Furthermore, what Gould saw as the radular teeth of a possible mollusk turned out to be perfectly good polychaete jaws that had rotated 90 degrees during preservation of some of the fossils. *Wiwaxia* was a polychaete worm, no doubt about it.

Your curiosity about *Wiwaxia* is shared. For people interested in fossil invertebrates, this funny little worm rivals more spectacular fossils like *Tyrannosaurus rex*. Indeed, at least one volunteer originally came to work in the Invertebrate Paleontology Section because of her fascination with *Wiwaxia*.

FREDERICK R. SCHRAM

*Dr. Frederick R. Schram was Curator of the museum's Fossil Invertebrate section at the Natural History Museum from 1991 to 1992. He is currently Professor of Systematic Zoology and Zoogeography at the University of Amsterdam.*

Courtesy of Dr. Desmond Collins, Department of Invertebrate Paleontology, Royal Ontario Museum, Toronto

*The museum's staff members are often asked to answer historical questions, or to identify artifacts and specimens that people have found, purchased, or inherited.* Exposition *is a* TERRA *feature in which the museum's staff will discuss interesting questions asked them by members and the general public.*

# Southland Diorama

## Southern California Hummingbirds and Their Nests

To those of us who immigrated to southern California from points east, one of the chief ornithological delights here is the abundance of hummingbirds. Four species of hummingbirds nest in the southern California coastal lowlands, and they are all readily attracted to feeders. Despite their willingness to approach humans closely, females of the local species are difficult to identify, since all four are essentially green above and light-colored below. Interestingly, they can be identified more easily by characteristics of their nests than by their appearance.

Anna's Hummingbird (*Calypte anna*) is the most common species throughout southern California. They occur here throughout the year, and are the most likely "owners" of local feeders. Where it is still possible, they tend to occupy native oak savannah and chaparral habitats, but they have also become well acclimated to urban gardens. There is good evidence that they undergo local seasonal migrations to higher elevations or deeper into the chaparral, but there always seems to be at least one dominant male Anna's in every local garden throughout the year.

Anna's Hummingbirds have been recorded nesting in every month of the year in southern California, but most pairs breed between late December and March, inexplicably at the coldest and wettest time of the year. The nest is typically placed near the tip of a low-hanging oak branch in a small fork, but they also frequently use exotic nesting locations, including the fronds of Australian tree ferns, pine trees, and hanging flower baskets. Anna's Hummingbird nests are made mostly of plant down, and are almost always heavily decorated with lichens, which are fastened to the outer walls of the nest with bits of cobweb.

The closely related Costa's Hummingbird (*Calypte costae*) is mainly a summer resident here, although a few may hang around feeders in the winter. On the coastal slopes they fiercely defend feeding territories in chaparral habitat, but tend to nest in cooler situations in small bushes overhanging streams from mid-April to late June. Elsewhere, they nest in the Lower Mojave Desert as early as late January or early February; in fact, they are the most common hummingbird species in local deserts. Their nest cups are shallower and flimsier than those of the Anna's, and they are decorated with various bits of dead leaves, tiny sticks, plant scales, and other brownish-colored bric-a-brac, but never with the silvery-gray lichens so characteristic of Anna's Hummingbird nests.

Black-chinned Hummingbirds (*Archilochus alexandri*) are strictly summer residents in southern California; they spend the winter in northern Mexico. They tend to occur in canyon and

Raymond J. Quigley

The Black-chinned Hummingbird makes its undecorated nest out of sycamore leaf down.

Opposite Top
Unlike the Anna's Hummingbird, to which it is closely related, the Costa's Hummingbird never ornaments its nest with lichens.

Opposite Bottom
The nest of the Allen's Hummingbird is heavily decorated with lichens.

riparian habitats, where they nest between mid-April and mid-June. Their nests are made almost entirely of the blond-colored down from the undersurfaces of sycamore leaves, lashed together with a dense network of cobwebs and most often placed near the tips of sycamore limbs. Black-chin nests are not decorated with lichens or other adornments, and can immediately be distinguished from other hummers' nests on the basis of this characteristic.

I have found all three species nesting at the same time within sight of each other along the little creeks and arroyos of Orange County's vast Rancho Mission Viejo: Anna's in the oak trees, black-chins in the sycamore trees, and Costa's in the willow and mulefat bushes along the stream.

The status of a fourth local hummingbird species, Allen's Hummingbird (*Selasphorus sasin*), is more enigmatic. For years it was known locally only as a breeding species from an isolated, non-migratory population (*sedentarius*) that occurred only on the Palos Verdes Peninsula and on some of the offshore Channel Islands. A separate, migratory population was known to occur from Ventura County north to about the Oregon state line. However, in 1978, Raymond Quigley and I were delighted to find an active Allen's Hummingbird nest in Escondido Canyon in Malibu (see photo), and other nests of the species have subsequently turned up elsewhere in Malibu, Marina del Rey, Newport, and even the Los Angeles Zoo. The species is apparently still expanding its local range, as the number of Allen's Hummingbirds recorded during local bird counts continues to increase. Most local Allen's Hummingbird nests have been found in April or May, although one active nest turned up in Zuma Canyon on a December Christmas count.

The nest of this species is similar to that of Anna's Hummingbird, being a relatively substantial cup made of green moss and heavily decorated with lichens, but the female Allen's has distinctly rufous sides, unlike the more common Anna's, which has entirely grayish-white underparts with a few green flecks. Like Anna's Hummingbirds, Allen's tend to continue decorating the nest during the course of incubation, and to add feathers from their own breasts to the lining of the inner cup.

LLOYD KIFF
*Director, Western Foundation of Vertebrate Zoology*

*Southland Diorama is a* TERRA *column that highlights the incredible diversity of animal and plant life still to be found in southern California. Selected issues will feature examples of the many species — extant and extinct, native and introduced, abundant and endangered — that are found in astonishing variety in one of the world's largest urban centers.*

Raymond J. Quigley

Raymond J. Quigley

# Focus on the West

## The Salton Sea

These glistening peaks of salt were the product of the New Liverpool Salt Company located on what is now the north side of the Salton Sea. The company established its plant in 1884 and enjoyed a lucrative business until 1905, when the great flood from the Colorado River covered the company's works and began filling the basin with water that would become the Salton Sea.

Between 1900 and 1905, over 10,000 people moved to the area that now surrounds the Salton Sea. During these years, the California Development Company began diverting water from the enormous Colorado River to create irrigation lands. Promoters established the Imperial Land Company, cleverly changed the name from the Salton Sink to the Imperial Valley, and generated publicity to entice people to move to the area.

As agricultural fields grew, the New Liverpool Salt Company's output increased. The company was located on a marsh that provided concentrations of relatively pure salt requiring minimal processing. Workers plowed the salt and piled it into mounds, where the severe desert sun and scant rain allowed it to dry quickly. Workers then ground the salt into small particles before bagging it and shipping it to market.

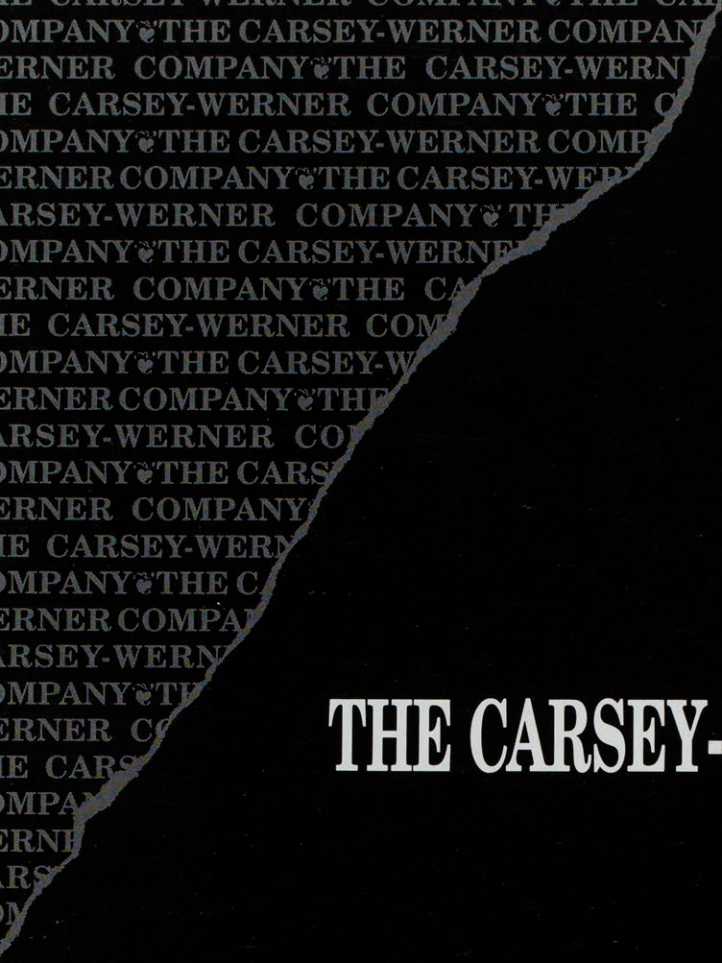
California ranked sixth in U.S. salt production, and the New Liverpool company played an important role in the state. The company probably would have continued to thrive for many years if the basin had not begun to flood in 1905.

The flood occurred after the California Development Company cut a new intake from the Colorado River. The planners failed to anticipate the unusually large seasonal swelling, lost control of the water, and fought dramatically for a year and a half as the river overflowed and eventually filled the basin with a lake 45 miles long, covering the New Liverpool Salt Company with 60 feet of water. Today the Salton Sea is continually fed by runoff water from adjacent fields, and thus remains a large body of salt water oddly placed in the middle of the desert.

Janet Evander
*Senior Collections Manager*
*Seaver Center*

Focus on the West *is a* TERRA *feature that presents the photographic highlights of the museum's Seaver Center for Western History Research. The Seaver Center is rich in photographs and other materials relating to the history of the American West.*

Putnam Valentine Collection (P-2.1), negative #P741

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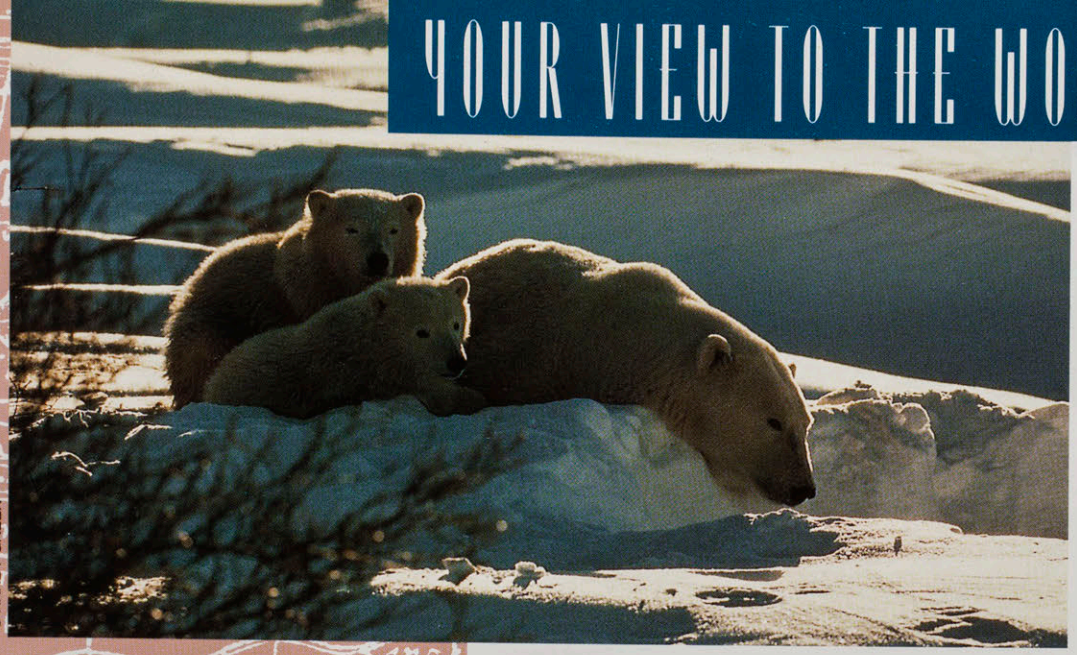

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